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Development and application of a program to modify attentional biases in dysphoria through eye-tracker technology

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DEVELOPMENT AND APPLICATION OF A PROGRAM TO MODIFY ATTENTIONAL BIASES IN DYSPHORIA THROUGH EYE-TRACKER TECHNOLOGY

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“Nuestra percepción de los hechos está más deformada por el peso de nuestras emociones que por la débil influencia de los datos que poseemos.”

John Verdon

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Information contained in the present dissertation

Part of the information described in the present dissertation has been previously published (or is under review) in the following works:

- **Blanco, I.,** Serrano-Pedraza, I., & Vazquez, C. (2017). Don't look at my teeth when I smile: Teeth visibility in smiling faces affects emotionality ratings and gaze patterns. Emotion, 17(4), 640-647. doi: 10.1037/emo0000260
- **Blanco, I.,** Poyato, N., Nieto, I., Boemo, T., Pascual, T., Roca, P., & Vazquez, C. Attentional biases in dysphoria when happy and sad faces are simultaneously presented. Cognition & Emotion (under review)
- Vazquez, C.*, **Blanco, I.** *, Sanchez, A., & McNally, R. J. (2017). Attentional bias modification in depression through gaze contingencies and regulatory control using a new eye-tracking intervention paradigm: study protocol for a placebo-controlled trial. BMC Psychiatry, 16(1), 439. doi: 10.1186/s12888-016-1150-9. (*Equal contributors)

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Cover design

The cover and the back cover of the present dissertation have been designed by the dissertation' author (Ivan Blanco). The design represents a real attentional pattern of one of the participants who was involved in one of the studies of the present thesis.

The faces used in the design correspond to the sad and happy expressions of the AF03 Model from the Karolinska Directed Emotional Faces (KDEF - Lundqvist, Flykt, & Öhman, 1998)[1]. This design has no any economic or commercial purpose.

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[1] For the KDEF faces data base see: Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska Directed Emotional Faces - KDEF, CD ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institutet, ISBN 91-630-7164-9.

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RESUMEN

Introducción

La depresión es un trastorno altamente prevalente, incapacitante, y que ocasiona un gran sufrimiento a nivel individual, y altos costes a nivel social (Murray & López, 1996; Kesler,2012). Aparte de los síntomas emocionales (i.e., estado de ánimo negativo, anhedonia, etc.), la depresión y la disforia están caracterizadas por la presencia de sesgos atencionales (i.e., una preferencia atencional a procesar la información negativa y a evitar la información positiva).

Según los modelos cognitivos, estos sesgos atencionales juegan un papel fundamental tanto en el inicio como en el mantenimiento del trastorno (Vazquez, Hervas, Hernangomez, & Romero, 2010). Debido a este papel central, se han desarrollado una serie de técnicas para intentar evaluar y modificar dichos sesgos atencionales en depresión (Duque, Lopez-Gomez, Blanco y Vazquez, 2015). Sin embargo, los procedimientos actuales de evaluación y modificación de los sesgos atencionales presentan una serie de limitaciones que reducen su fiabilidad, la generalización de sus resultados, y la eficacia de los programas de modificación de sesgos atencionales.

Con los estudios presentados en esta tesis se espera desarrollar y aplicar un programa de modificación de sesgos atencionales en disforia, a través del uso de tecnología de movimientos oculares, intentando superar las limitaciones de los estudios previos.

Objetivos

El objetivo principal de la presente tesis es el desarrollo y aplicación de un programa de modificación de sesgos atencionales en disforia a través del uso de tecnología de movimientos oculares superando las limitaciones de los estudios previos en la evaluación y la modificación de dichos sesgos. Para este propósito, el primer objetivo fue desarrollar y validar una serie de estímulos (i.e., caras felices) controlando la saliencia visual de los dientes, la cual podría afectar la evaluación de los sesgos atencionales. El siguiente objetivo fue evaluar los sesgos atencionales controlando dicha visibilidad de los dientes de las caras felices. A su vez, se pretendía evaluar los sesgos atencionales cuando la información emocional es presentada de forma simultánea, y si la presencia de sesgos atencionales varia en relación la sintomatología depresiva de los participantes. Por último, se desarrolló el paradigma de modificación de sesgos atencionales evaluando su eficacia para modificar los patrones atencionales, así como variables relacionadas (sintomatología depresiva, estado de ánimo y vulnerabilidad al estrés) en participantes disfóricos.

Resultados

Resumiendo los resultados principales de la presente tesis, se encontró que la visibilidad de los dientes de las caras felices altera los juicios emocionales que se emiten sobre ellas, así como los patrones atencionales cuando éstas son procesadas. A su vez, se encontró que los participantes con alta sintomatología depresiva mostraban un sesgo atencional de evitación de las caras felices cuando éstas se presentaban emparejadas tanto con caras neutras como con caras tristes. A su vez, los participantes con niveles medios de sintomatología depresiva presentaban mayor sesgo de evitación de las caras felices cuando se presentaban emparejadas con caras tristes que cuando se presentaban emparejadas con caras neutras. Por último, en relación al programa de modificación de sesgos atencionales, no se encontró ningún efecto del mismo en los patrones atencionales ni en la sintomatología depresiva o la vulnerabilidad al estrés.

Conclusiones

Con los estudios desarrollados en la presente tesis se pretendía desarrollar y aplicar un programa de modificación de sesgos atencionales en disforia que permitiera superar las limitaciones de los estudios previos. A pesar de que el programa de modificación de sesgos no mostró resultados significativos, los estudios presentados en la presente tesis arrojan algo de luz para el desarrollo de nuevas tareas de evaluación y modificación de sesgos atencionales. En primer lugar, nuestros estudios apuntan a la necesidad de controlar el efecto que algunas variables (p. ej., la visibilidad de los dientes) podrían tener a la hora de evaluar los sesgos atencionales. En segundo lugar, la aparición de sesgos atencionales parece variar en función del nivel de sintomatología depresiva. Además, la presentación simultánea de caras emocionales para evaluar sesgos atencionales podría ser una buena estrategia en estudios futuros, ya que parece fomentar la aparición de los sesgos atencionales en participantes con niveles medios de disforia. Por último, es necesaria más investigación para desarrollar procedimientos de modificación de sesgos atencionales que permitan evaluar la eficacia de estos programas y su utilidad como herramientas terapéuticas.

SUMMARY

Introduction

Depression is a highly prevalent, disabling disorder that leads to great suffering at the individual level and high societal costs (Murray & Lopez, 1996; Kesler, 2012). Apart from emotional symptoms (i. e., negative mood, anhedonia, etc.), depression and dysphoria are characterized by the presence of attentional biases (i.e., an attentional preference for processing negative information and avoiding positive information).

Following cognitive models, these attentional biases play an important role in both the onset and maintenance of depression (Vazquez, Hervas, Hernangomez, & Romero, 2010). Due to these biases' central role in depression, a number of techniques have been developed to evaluate and modify this biased attention (Duque, Lopez-Gomez, Blanco and Vazquez, 2015). However, the current procedures for assessing and modifying attentional biases present some limitations that reduce their reliability, their effectiveness, and the generalization of their results.

The studies presented in this thesis, aimed to develop and apply a program to modify attentional biases in dysphoria through the application of eye-tracker technology overcoming the limitations of previous studies.

Objectives

The main objective of this thesis is to develop and ultimately apply a new attentional bias program to reorient attention and reduce attentional biases in dysphoria through the use of eye-tracking technology, overcoming some of the limitations of previous studies in the evaluation and modification of such biases. For this purpose, the first objective was to develop and validate a series of stimuli (i. e., happy faces)

controlling for the visual salience of teeth visibility which might affect the assessment of attentional biases. The next objective was to assess attentional biases, controlling for the visibility of the teeth of the happy faces. At the same time, the attentional biases that appear when emotional information is presented simultaneously were assessed and whether the presence of attentional biases is related to the participants' depressive symptomatology was tested. Finally, a new program to modify attentional biases was developed, assessing its effectiveness in modifying attentional patterns, as well as related variables (depressive symptomatology, mood and vulnerability to stress), in dysphoria.

Results

Summarizing the main results of this thesis, teeth visibility was found to alter the emotional judgments that are made on happy faces, as well as the attentional patterns that occur when they are being processed. Moreover, it was found that participants with high depressive symptomatology showed an attentional bias to avoid happy faces when they were paired with neutral or sad faces. Additionally, participants with medium levels of depressive symptomatology showed greater avoidance bias of happy faces when they were paired with sad faces than when they were paired with neutral ones. Finally, regarding the new attentional bias modification program, no effect was found on attentional patterns, depressive symptomatology or vulnerability to stress.

Conclusions

The studies presented in this thesis were carried out to develop and apply a program to modify attentional biases in dysphoria improving upon some of the methodologies and limitations of previous studies. Although our bias modification program did not show significant results, the studies presented in this thesis shed some light on the development of new tasks to both assess and modify of attentional biases. On one hand, our studies point out the need to control for the effect that some variables (e. g., teeth visibility) might have when assessing attentional biases. On the other hand, attentional biases towards emotional stimuli appear to vary depending on the level of depressive symptoms. Further, simultaneous presentations of emotional faces to assess biased attentional patterns may be a good strategy to use in future studies, as it seems to make evident the attentional biases in participants with medium levels of dysphoria. Finally, more research is needed to develop refined procedures to modify attentional bias in depression and to assess the potential effectiveness and utility of these programs as clinical tools.

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PREAMBLE AND OBJECTIVES

"Reality is relative, depending on what lens you look through"
Sylvia Plath

Perception and attention are the main doors to processing the world around us. However, human beings do not process reality as it is. Instead, we filter and select all the information that we attend to. Let us imagine the view from the top of a hill on a summer afternoon. Although most people would probably process the same scene, if a geologist and a photographer were both observing it, the geologist would probably pay attention to the type of soil, the type of rock, the orography of the area, and so on. Whereas, the photographer would probably pay more attention to the frame, to how the sun is projected on the mountains, to the lights and shadows that are generated between the trees, etc. Thus, although the scene is the same, the things that we pay attention to depend on a series of both external and internal variables that modulate our attention.

On the one hand, some external cues or features that are present in our perceptual field can exogenously draw our attention to them. For instance, following the example above, it would be more likely that the geologist and the photographer perceive a red car parked in the middle of the forest, surrounded by green trees earlier, than a green car parked in the same place. Therefore, the salience of some information can guide our attention. However, on the other hand (and more importantly for the main goal of the current thesis), some internal aspects of the human being such as our previous experiences, our cognitive schemas or our emotions can endogenously guide our attention. For instance, if our photographer is afraid of spiders, it is more likely that she would be more alert to any spider's cues (in this nature environment) and, therefore would perceive a spider or a spider web close to her faster than our geologist. Further, in this situation, our photographer can also use her attention in an attempt to regulate her internal processes. Indeed, she might maintain her attention on the spider trying to control his position while she tries to escape from the situation or, instead, she might draw her attention away from the spider in order to avoid the negative feelings associated with seeing the spider. Therefore, emotions and cognitions can bias and modulate our attention, but we can also use our attention to regulate our emotions and cognitions.

As clinical psychologists, and due to the relevance of attention in both cognitive and emotional components of human beings, it is important to understand and disentangle the attentional mechanisms that underlie psychopathology. Current cognitive models of psychopathology have proposed that attentional biases (i.e., the tendency to attend to some information over other information) play an important role on both the onset and maintenance of different disorders such as depression (Beck 1967, 2008; Vazquez, Hervas, Hernangómez, & Romero, 2010; Gotlib & Joormann, 2010). In fact, depression seems to be characterized by a preferential attention to negative information and the decreased processing of positive information (Duque & Vazquez, 2015). Thus, in the present dissertation we investigated the possibility of modifying these attentional biases through the development and the application of a new attentional training, based on an eye-tracking procedure, in people with high levels of symptoms of depression.

Therefore, the **main goal** of the present dissertation was to develop and apply a new eye-tracking procedure to modify attentional biases, in a dysphoric sample, overcoming the limitations of previous research on attentional biases and attentional bias modification. As part of the research process, we wanted to control as many methodological aspects as possible that are involved in the development and application of the attentional training. In order to accomplish this objective, we conducted a series of studies where various secondary objectives were accounted for.

First, we wanted to control the stimuli that we used to assess attentional biases. Typical attentional biases studies have used dysphoric related stimuli such as sad or happy faces to assess attentional biases in depression. However, research on emotional processing has found that some psychophysical features of the stimuli (i.e., contrast energy or luminance of the stimuli) and, specifically, certain features of happy faces (e.g., teeth visibility) can exogenously draw participants' attention to them (Calvo & Nummenmaa, 2008, 2011; Savage, Lipp, Craig, Becker, & Horstmann, 2013). As previous research on attentional biases has not controlled these effects, and in order to control them in our bias assessment, in the **first study** of the current dissertation (**chapter 3**) we developed and validated a set of happy faces controlling the influence of teeth visibility and low-level features. Specifically, we aimed to evaluate the influence of teeth visibility on the prototypicality and emotional intensity of happy faces and to explore the attentional patterns when happy faces (with and without teeth visibility) are processed.

Second, studies on attentional biases have traditionally assessed attentional processing using emotional stimuli such as sad, happy or angry faces that compete with neutral faces for participants' attention. Moreover, no study to date has evaluated the attentional performance of people with high levels of depression when two types of emotional stimuli are presented simultaneously (e.g., a happy face paired with a sad one). Therefore, as these types of co-occurrences are common in real-life situations, the **second study** of the current dissertation (**chapter 4**) aimed to assess attentional biases on these types of emotional pairs of stimuli, and compare them with the attentional biases that emerge in the typical pair of stimuli used (i.e., happy vs. neutral; and sad vs. neutral faces). Another goal of the second study was to assess differences in attentional biases between participants with varied levels of depressive symptoms. Further, the faces developed and validated in the previous study were used to evaluate attentional biases when psychophysical properties of the stimuli are controlled.

Finally, the **third study** of the current thesis (**chapter 6**) consisted of the application of the attentional bias training itself. Previous research in attentional bias modification presented some methodological limitations that we aimed to overcome. Therefore, the main goal of this study was to modify the double attentional bias typically found in depressive and dysphoric participants (i.e., the preferential processing of negative information and difficulties engaging attention to positive information) through our new eye-tracking paradigm. Furthermore, a second goal of this study was to evaluate the transfer effects of changes in attentional biases on related variables such as psychological measures, interpretation biases and stress vulnerability. (For a summary of the goals of this dissertation, see Table 1).

Table 1. Summary of the objectives of the current dissertation

Main goal: Development and application of a new eye-tracking procedure to modify attentional biases, in a dysphoric sample, overcoming the limitations of previous research.

Chapter	**Objectives**
Chapter 1: Cognitive biases in depression: the role of attention	Review the theoretical background regarding cognitive biases and depression focusing on the role that attentional biases play in depression.
Chapter 2: Limitations of current eye-tracking attentional bias assessment	Describe the main limitations of the assessment of attentional biases through eye-tracking methodologies focusing on the type of emotional stimuli used and its presentation
Chapter 3: *Emotional stimuli validation*	Development and validation of a series of stimuli controlling the influence of teeth visibility and low-level features. - Evaluate the influence of teeth visibility on the prototypicality and emotional intensity of happy faces (Study 1). - Explore the attentional patterns when happy faces (with and without teeth visibility) are processed (Study 2).
Chapter 4: A*ttentional bias assessment*	Assess attentional biases when emotional information (i.e., happy vs. sad faces) are presented simultaneously. Assess differences in attentional biases regarding the level of depressive symptoms. Assess attentional biases when the psychophysical properties of the stimuli are controlled.
Chapter 5: Modification of attentional biases in depression	Describe the current literature of attentional biases modification, focusing on the limitations of current procedures.
Chapter 6: *Attentional bias training through an eye-tracker based paradigm: a proof of principle study*	Application of the attentional bias training. - Modify the double attentional bias typically found in depressive and dysphoric participants. - Evaluate the transfer effects of changes in attentional biases on related variables.
Chapter 7: Conclusions and general discussion	Summarize the major findings of the present dissertation and discuss them with regard to the evidence in the field.

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CHAPTER 1: COGNITIVE BIASES IN DEPRESSION: THE ROLE OF ATTENTION

Depression is a very common form of psychopathology associated with adverse personal (individual suffering, suicide) and societal costs (sick leave, treatment costs) – (for a review, see Kessler, 2012). Therefore, it is not surprising that suffering from depression leads to a prominent decrease in the quality of life, happiness, and life satisfaction of the people who suffer it (Bergsma, Veenhoven, Have & Graaf, 2010, Vazquez, Rahona. Gómez, Felix-Caballero & Hervas, 2015) as well as high rates of disability due to the disorder. Epidemiological reports, as *The Global Burden of Disease* (The World Health Organization – WHO, Murray & Lopez, 1996), have shown that depression is the fourth leading cause of disability worldwide. As prevalence rates are increasing, it has been also estimated that by 2020 depression will be the second leading cause of disability (Murray & Lopez, 1996). Currently, the 12-month prevalence rates of depression in Europe reach 6.9% (Wittchen et al., 2011) whereas the lifetime prevalence rate in Spain is around 4.0% (Bromet et al., 2011).

Despite the wide range of pharmacological and psychological interventions available, existing treatments for depression have shown limited efficacy and unwanted side effects (Cuijpers, van Straten, Bohlmeijer, Hollon, & Andersson, 2010; Turner, Matthews, Linardatos, Tell, & Rosenthal, 2008). Additionally, although some of the current interventions are efficacious in the short term, relapse is common after the first episodes of depression are resolved. In fact, at least 50% of those who recover from an episode of depression experience a subsequent episode in the following year (Kessler, Xhao, Blazer & Swartz, 1997). Unfortunately, these prevalence rates increase to 85% in a period of 15 years (Mueller et al., 1999). Therefore, clinical researchers have endeavoured to identify core mechanisms involved in the development and maintenance of depression as potential targets for novel interventions.

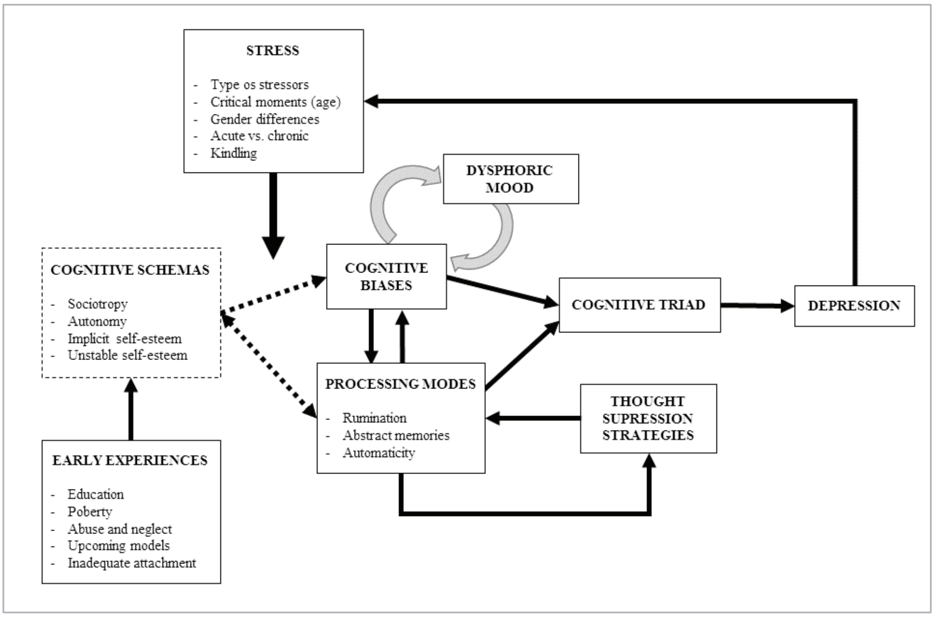
1.1.The cognitive models of depression

Beck's (1967) cognitive model of depression highlights that early adverse events lead to a cognitive vulnerability (i.e., dysfunctional cognitive schemas). These dysfunctional schemas, activated by high intensity life stressors, lead to various forms of dysfunctional information processing such as attentional biases to schema-congruent information (e.g., attentional biases towards negative information) or negatively biased interpretations of ambiguous information. As a product of the continuous repetition of this pathway, negative beliefs regarding themselves, the world and the future (i.e., the cognitive triad) are activated, and consequently, the depressive disorder emerges.

Other models of depression have proposed the idea of an associative network of depressive elements (Bower, 1982; Teasdale, 1988). For instance, Teasdale (1988) suggested the *Differential activation hypothesis*. According to this model, previous depressive episodes facilitate the activation or accessibility of dysfunctional schemas and the biased processing of information during dysphoric mood, which, in turn, lead to dysphoric mood again. Therefore, a bidirectional cycle between those elements emerges. The continuous activation of this cycle enhances the strength of the association between the depressive elements and leads to a higher sensitivity of the network for being activated by life stressors. Thus, a wide range of stressors, but less intense, may facilitate the appearance of an depressive episode. This phenomenon has been described by Beck (2008), in a reformulation of his cognitive model, as the *"kindling"* effect: *"milder stressful life events provide an alternate pathway to* *depression in vulnerable individuals. Moreover, the triggering events of successive episodes of depression become progressively milder"* (Beck, 2008, p. 970).

In order to integrate all the previous clinical and experimental evidence, Vazquez, Hervas, Hernangómez, & Romero (2010) proposed an integrative cognitive model of depression (see Figure 1.1).

Figure 1.1. Integrative cognitive model of depression (Vazquez et al., 2010)



In this model, the dysfunctional schemas are also preceded by early adverse events. However, the activation of the schemas is not only caused by high-intensity stressors. In fact, low-intensity but chronic stressors also can lead to the activation of these dysfunctional schemas. Further, this model posits that depression itself can be a stressor that activates dysfunctional schemas due its impact on patients' daily lives. The activation of dysfunctional schemas leads to not only the appearance of cognitive biases but also to some dysfunctional processing modes. Many of these dysfunctional processing modes have not been taking in account in the classical models, such as rumination or thought suppression strategies that are bidirectionally related to cognitive biases. Following Teasdale (1988), these authors also argue that cognitive biases are also bidirectionally associated with dysphoric mood. Therefore, a vicious cycle between dysphoric mood, cognitive biases, and dysfunctional processing modes lead, in the end, to the appearance of the cognitive triad and the depressive disorder itself (Vazquez, et al., 2010). Additionally, the model also integrates the idea of the *kindling* effect (Teasdale, 1988; Beck, 2008) to explain the high rates of recurrence and relapse in the disorder.

Finally, it is important to note that current cognitive models of depression conceptualized these cognitive biases as a causal factor for the development of depression and not a mere symptom of the disorder. Therefore, the study of this biased cognition is fundamental to understanding the disorder and to developing new clinical strategies to prevent and treat it.

1.2.Cognitive biases in depression

Although the next section will be focused on the role of attentional biases in depression, it is important to review the existing research evidence on other cognitive biases (i.e., memory and interpretation biases) that are, in fact, closely related to attentional biases. Thus, first, we will summarize the latest research regarding both memory and interpretation biases and, then, we will review the literature regarding attentional biases and the role that they play in depressive disorders.

1.2.1. Memory biases

Memory biases have been widely studied in depression and were traditionally considered the hallmark of cognitive problems associated with the disorder. In fact, there is meta-analytic evidence regarding the relationship between explicit memory biases and depressive mood. For instance, in a classic meta-analysis, Matt, Vazquez, & Campbell (1992) meta-analyzed 58 studies (N = 2050) regarding mood-congruent recall of affective stimuli on clinically depressed, subclinically depressed, induced depressed mood, induced elated mood, and normal non-depressed participants. The authors found that while normal non-depressed participants showed a bias to recall more positive than negative stimuli, clinically depressed participants exhibited a mood-congruent biased recall of similar magnitude, but in the opposite direction (i.e., greater recall of negative than positive stimuli). Further, induced depressed participants also showed a biased recall of negative information.

Similar findings have also been found in a meta-analysis regarding implicit mood-congruent recall in depression (Gaddy & Ingram, 2010). The authors concluded that while non-depressed participants showed a preferential bias to implicit recall of positive words, clinically depressed and depressed induced participants showed the opposite bias (i.e., a preferential implicit recall of negative words) – (Gaddy & Ingram, 2010). Therefore, depression, and depressed mood, seem to be related to both an explicit (Matt, Vazquez, & Campbell, 1992) and implicit (Gaddy & Ingram, 2010) memory bias towards negative information.

The role of memory biases in depression not only has been studied regarding the recall of explicit and implicit memory but also with regard to autobiographical memory. Williams and Broadbent (1986) conducted a study where suicidal patients and community controls had to recall autobiographical memories regarding a given cue (i.e., a positive or a negative cue). These authors found that, in addition to higher reaction times to responding to the cues, suicidal patients recalled more general memories (e.g., *"the summer at my grandparent's house"*), to both positive and negative cues, than community controls. Further, subsequent studies found that this overgeneral autobiographical memory effect also differed in the content of the non-specific memories. For instance, Williams and Dritschel (1992) found differences between suicidal patients and healthy controls in the number of general but categorical memories (e.g., "*I am not good playing tennis, I always lose the matches*") retrieved, but not in the number of general-extended memories that were recalled (e.g., *"my holidays at London"*). Additionally, in a free-recall study in which dysphoric and non-dysphoric' participants were compared, Romero, Sanchez, & Vazquez (2014) found that dysphoric participants recalled less specific positive memories, but not less specific negative memories, than the non-dysphoric group. Further, the authors also found that the dysphoric participants recalled higher proportions of both categorical and extended memories than the non-dysphoric group.

Therefore, there is extensive literature regarding the overgeneral autobiographical memory phenomenon in depression. In fact, meta-analytic and literature reviews highlight that overgeneral autobiographical memory is a consistent characteristic of depression that, indeed, predicts the course of the disorder (see van Vresswijk & de Wilde, 2004; Williams et al., 2007; and Sumner, Griffith, & Mineka, 2010).

1.2.2. Interpretation biases

In everyday life, we face a wide variety of situations in which other people's behaviour, or the development of the situations themselves, can be ambiguous. For example, we could be walking down the street and see an old-classmate who does not greet us. In this situation, people tend to look for an interpretation of this behaviour. On the one hand, some people might interpret this situation by thinking: *"My old classmate did not greet me because he did not recognize me. It has probably been too long, and I have changed a lot since school*." On the other hand, some people might interpret this situation with thoughts like: *"He did not want to greet me. He probably never liked me."* It seems logical that the second interpretation might be related to an increase of negative mood and other negative thoughts. However, extant evidence has shown that depressed mood previous to the ambiguous situation is also related to the interpretation that we have for it. In fact, in a recent meta-analysis, Everaert, Podina, & Koster (2017) meta-analyzed 87 studies (N = 9443) regarding interpretation biases to ambiguous information in clinically depressed patients, participants with elevated depressive symptoms and remitted depressed participants. These authors found a medium overall effect size for both a negative interpretation bias (g = 0.58) and lack of a positive interpretation bias (g = 0.60). Therefore, in contrast to healthy individuals who show a positive interpretation bias, depression is also related to a bias for interpreting ambiguous information more negatively (Wisco, 2009) and less positively (Everaert, Podina, & Koster, 2017).

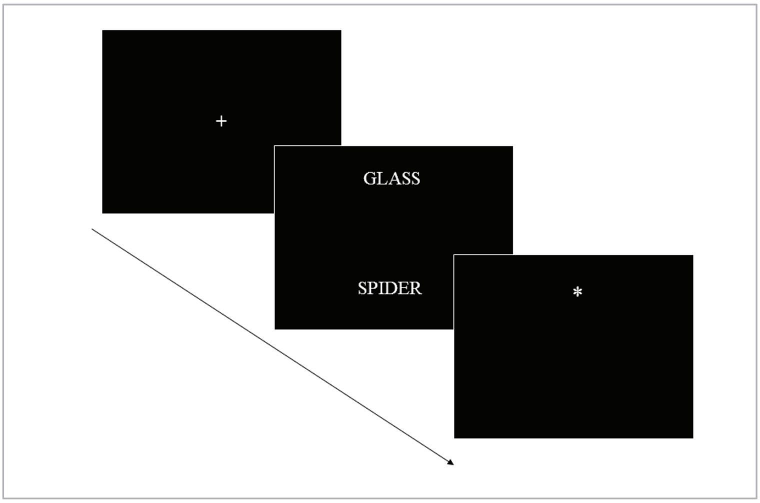
1.2.3. Attentional biases

Following Posners' attentional model (Posner & Petersen, 1990; Petersen & Posner, 2012), researchers have posited that attentional biases in emotional disorders can emerge at different stages of the attentional process. Components of visual attention at different stages of attentional processing (e.g., orientation, engagement, disengagement, maintenance of attention) have been defined as two different processes:

vigilance and maintenance attention to emotional information. On the one hand, the attentional vigilance process can be defined as an automatic process in which attention is driven, exogenously, by the stimuli. Thus, vigilance is composed of more automatic components of attention such as orientation or latency detection time of emotional stimuli. On the other hand, the attentional maintenance process can be defined as a more controlled or voluntary process in which attention is driven, endogenously, by the person's goal-directed system. Thus, maintenance is composed of later stage components such as the total time devoted to emotional stimuli. In sum, attentional biases can be assessed at different stages of the attentional process and can be driven by exogenous or endogenous cues (see Armstrong & Olatunji, 2012). Therefore, the aim of attentional paradigms designed to assess attentional biases should be to capture the specific components of attention that are involved in the differential processing of emotional information in each disorder.

Attentional biases to emotional information in depression have been assessed through a variety of experimental paradigms and methodologies. In many experiments, investigators used procedures based on reaction times (Peckham et al., 2013; Winer & Salem, 2016). One of the most commonly used paradigms to assess attentional biases to emotional information in depression is the well-known dot-probe task (MacLeod, Mathews, & Tata, 1986). This task was translated from the study of attentional biases in anxiety disorders. In the original study, a pair of words (e.g., one neutral and the other threat-related) appeared on a computer, one above the centre screen and one below the centre screen. After 500 ms, the word pair vanished, and a dot appeared in the location previously occupied by one of the words. Clinically anxious patients and control participants were told to push a button to indicate the dot's position as soon as they detected the dot (see Figure 1.2).

Figure 1.2. Example of neutral vs. anxiety-related word trial of a classical dot-probe task.



The rationale of this paradigm is that a quicker response to the dot when it occurs in the previous location of a threatening stimulus reveals attentional vigilance for threat. In this seminal study, authors found that clinically anxious participants showed shorter detection latency times of the dot than normal control participants when the dot followed the threatening stimuli. Then, this result was interpreted as an attentional vigilance for threatening information in a clinically anxious population (MacLeod, Mathews, & Tata, 1986).

The dot-probe paradigm has been modified to adapt it to the assessment of attentional biases in depression samples. In these procedures, depression-related stimuli compete with neutral information to draw participants' attention. These stimuli usually consist of pairs of emotional and neutral objects including faces (Gotlib, Krasnoperova, Yue, & Joormann, 2004), images (Shane & Peterson, 2007, Experiment 1) or words

(Bradley, Mogg, & Lee, 1997). Further, the exposure time of the stimuli in depression studies has been manipulated. As research has shown that longer stimuli presentation times enable the emergence of attentional bias in depression, stimuli in studies in depression are presented for more time than stimuli in the original anxiety-related paradigm (Mogg, Bradley, & Williams, 1995). Research using this approach has consistently found that, in general, depressed participants show an attentional bias towards negative stimuli. For instance, Mogg, Bradley, and Williams (1995) using a modification of the dot probe task with two stimuli exposure conditions (i.e., short and long exposure), presented anxiety and dysphoric related words (paired with neutral words) to a sample of anxious, depressed and normal control participants. The authors found that, in comparison to normal control participants, depressed participants showed greater overall bias for negative words but only at longer exposure times (i.e., 1000ms) – (Mogg, Bradley, & Williams, 1995). In another dot-probe study, Gotlib, et al. (2004) used emotional faces (i.e., happy, sad and angry faces), paired with a neutral face, to assess attentional biases in clinically depressed participants, participants with generalized anxiety disorder and non-psychiatric controls. The authors found that clinically depressed participants were faster than non-psychiatric controls at detecting the dot when it appeared after replacing the sad faces. In other words, compared to non-psychiatric participants, clinically depressed participants showed an attentional bias to sad faces (Gotlib et al., 2004). These results have been supported by meta-analytic evidence regarding the dot-probe task. A meta-analysis conducted by Peckham, McHugh, and Otto (2010) showed that depression is characterized by a preferential processing of negative information regardless of the stimulus modality used in the studies.

Despite its widespread use, the application of the dot-probe task to assess attentional biases in depression has been widely criticized. First, in general, the use of reaction time tasks for comparing the performance of depressed patients and healthy participants is controversial due to the overall deficits of depressed individuals in their executive functions (Miller, 1975; Snyder, 2013). Thus, assessing attentional biases to emotional information in depression through reaction time measures may artificially increase the differences between clinical and healthy populations and lead to ambiguous conclusions regarding the nature of the observed biased attention. Second, researchers have argued that dot-probe paradigms do not allow the continuous assessment of attention. Thus, the paradigm cannot capture the complexity and dynamic nature of the attentional processing (e.g., attentional shifts and fixations). Although researchers have made several attempts at refining dot-probe paradigms, trying to assess different components of attention (e.g., orientation, engagement, disengagement, etc.), these paradigms only provide a fixed snapshot of the attentional processing without clearly differentiating between early vs. later stages of attentional processing (see Koster, Crombez, Verschuere, & De Houwer, 2004; and Armstrong & Olatunji, 2012).

Due to the limitations of reaction time paradigms, and the development of new technologies, researchers have developed increasingly refined methods for isolating the pathogenic role of attentional biases in depression such as eye-tracking procedures.

1.2.3.1. Attentional biases in depression and their assessment through eye-tracking paradigms

Eye-tracking procedures allow researchers to assessing attention and its components in a continuous and a direct manner. For instance, eye-tracking paradigms facilitate the assessment of different attentional indexes such as initial orientation, latency time, first fixation duration, number or total duration of fixations, etc., that capture the attentional process at different temporal stages (see Armstrong & Olatunji, 2012). Accordingly, the use of eye-tracker paradigms has revealed that, in contrast to other emotional disorders such as anxiety, which is characterized by a rapid orientation to anxiety-related stimuli (i.e., threatening stimuli) at early stages of attentional processing, depression is characterized by sustained attention to dysphoric-related information at later stages of attentional processing (Gotlib & Joormann, 2010; Armstrong & Olantunji, 2012; Platt, Waters, Schulte-Koerne, Engelman, & Salemink, 2016). In a recent study where emotional faces (i.e., happy, sad and angry) were presented alongside neutral faces in a free-viewing task, Duque and Vázquez (2015) found that clinically depressed participants spent more time looking at sad faces than never-depressed participants. Further, the authors found that clinically depressed participants also spent less time looking at happy faces than never-depressed participants (Duque & Vazquez, 2015). Using a similar set of stimuli and methodology, Sanchez, Vazquez, Marker, Le Moult, and Joormann (2013) found that clinically depressed individuals had difficulties disengaging from sad faces in trials where participants were required to look at the non-sad face of the pair (i.e., the neutral face). However, the authors found no significant differences between groups regarding their ability to disengage from happy faces in trials where participants were required to look at the neutral face (Sanchez et al., 2013). Therefore, depression seems to be characterized by a double attentional bias to emotional information. First, depressed participants showed an attentional preference for negative emotional information. Depressed patients devoted more time to processing negative information (i.e., maintenance of attention on negative stimuli) and showed difficulties disengaging their attention from it once the negative stimuli had captured their attention. Second, depressed patients also devoted less time to processing positive information (i.e., less maintenance of attention on positive stimuli) and did not show difficulties disengaging their attention from it, indicating that an attentional bias away from positive information is also associated with depression (Armstrong & Olatunji, 2012).

It is important to note that attentional biases in depression are not restricted to the processing of negative information. In contrast to healthy people (Hilt & Pollak, 2013; Sanchez & Vazquez, 2014), depressed participants also show a decreased attention to positive information (Kircanski, Joormann, & Gotlib, 2012). Thus, an "anhedonic bias" (i.e., less attention to positive information) emerges when the attentional performance of depressed patients is compared to the attentional performance of never-depressed participants.

Interestingly, these two opposite types of attentional biases towards emotional faces have also been found in dysphoric samples. For instance, Leyman, De Raedt, Vaeyens, and Philippaerts (2011) conducted a study where emotional faces (i.e., happy, sad, and angry) and a neutral face were presented simultaneously to dysphoric and non-dysphoric participants while their eye-movements were recorded. The authors found that whereas non-dysphoric participants spent more time looking at happy faces, the dysphoric participants spent significantly more time looking at the sad ones. Further, the analysis also revealed that the time that dysphoric participants devoted to processing sad faces (i.e., fixations and saccadic movements within the sad faces) was longer than the time devoted by non-dysphoric participants (Leyman et al., 2011). In another eye-tracking study with a dysphoric and non-dysphoric sample, Sears, Thomas, LeHuquet and Johnson (2010) used two different presentation conditions (i.e., simultaneous and sequential presentation) of depressed-related, anxiety-related, positive and neutral pictures to assess both maintenance and disengagement components of attention. In the simultaneous condition, the four emotional pictures were presented at the same time, in each quadrant of the screen, and participants were instructed to freely look at the screen. Analysis of this simultaneous condition found that, compared to non-dysphoric participants, dysphoric participants spent less time looking and making fixations on the happy faces. In the sequential condition, one emotional picture was displayed in one of the quadrants of the screen. Afterwards, a superimposed arrow appeared in the centre of the emotional picture pointing out of the emotional image to another quadrant of the screen. Participants were told that they must look, immediately, to the quadrant indicated by the arrow. Results revealed that dysphoric participants were slower than non-dysphoric participants at disengaging their attention from depressed-related pictures. Therefore, dysphoric people seem to show the same attentional biases as clinically depressed populations.

Additionally, within dysphoric samples, it has been proposed that biases in attention are significantly higher for participants with high depression scores than for participants with low depression scores (Everaert, Duyck & Koster, 2014). Thus, it seems that the association between attentional biases and level of depression follows a gradient. Some support for this claim is provided by meta-analytic evidence. Amstrong & Olatunji (2012) found that the only moderator of the magnitude of the effect size of attentional biases in depression was the clinical condition of participants. Studies in which participants met clinical criteria for major depressive disorder found a more robust attentional bias than those studies in which dysphoric participants were selected based on a cut-off score for a measure of depression symptoms (Armstrong & Olatunji, 2012). Therefore, considering the available evidence examined here, the dysphoric mood is also associated with the presence of a double attentional bias (i.e., attention towards negative information and away positive one) and difficulties disengaging from negative information, although the magnitude of the attentional biases depends on the severity of depressive symptoms.

1.2.3.2. The causal role of attentional biases

If cognitive models consider these attentional biases as a vulnerability factor for depression, rather than merely a symptom of the disorder, that plays an important role in the etiology and also the maintenance and subsequent relapses of the disorder (Beck, 1976, 2008; Teasdale, 1988; Vázquez et al., 2010), then a question arises: Do attentional biases to emotional information remain stable after the depressive disorder has remitted?

Some researchers have tried to analyze attentional biases in remitted depression samples although the number of studies is scarce. Moreover, the few studies designed for this purpose have yielded mixed results. Using a dot-probe paradigm where happy and sad faces were presented, paired with a neutral face, to a sample of currently depressed-patients, remitted-depressed patients and never-depressed patients, Joormann and Gotlib (2007) found that, compared to the never-depressed participants, the currently depressed and remitted-depressed patients showed a greater attentional vigilance bias to sad faces. Further, compared with both groups of patients, the never-depressed participants exhibited a greater attentional vigilance to happy faces. Importantly, there were no differences in the vigilance to either sad or happy faces between current and remitted-depressed groups (Joormann & Gotlib, 2007). Thus, it seems that attentional biases remain stable after remission of the disorder.

Although these results were replicated in a similar dot-probe study (see Fritzsche et al., 2010), studies using eye-tracking methodologies have found inconclusive results. For example, Sears, Newman, Ference, & Thomas (2011) compared the attentional performance of never-depressed, remitted-depressed and dysphoric groups in a free-viewing eye-tracker task. Depression-related, anxiety-related, positive and neutral pictures were presented simultaneously. Analysis revealed that compared to never-depressed participants, remitted-depressed and dysphoric participants exhibited a bias away from the positive pictures. In other words, both groups (remitted depressed and dysphoric) spent less time looking at happy faces than their never-depressed counterparts (Sears, et al., 2011). However, other eye-tracking studies failed to find this difference. In fact, in an eye-tracking study conducted by Isaac, Vrijsen, Rinck, Speckens, and Becker (2014) participants were instructed to freely look at the screen while three emotional images (i.e., happy, sad, angry), and their paired neutral image, were displayed at the same time. These authors found that, compared to clinically depressed participants, never-depressed participants spent significantly more time looking at happy faces. Further, there were no differences in the time that never and remitted-depressed participants devoted to processing happy faces.

Therefore, mixed results have been found depending on the methods and the stimuli used to assess attentional biases in remitted depressed populations. Also, some researchers have pointed out that, after a depressive episode, cognitive biases remain stable but in a latent state. Thus, activation of these attentional biases would only occur under certain circumstances such as experienced negative mood or facing a stressor

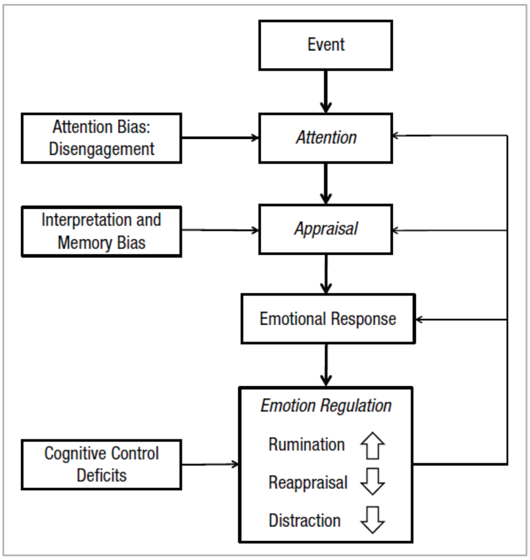
(Scher, Ingram, & Segal, 2005). In conclusion, more research is needed to clarify the role that attentional biases play after the remission of depressive episodes.

1.3.The interrelation between cognitive biases: the role of attention

As described above, in contrast to healthy individuals (characterized by a preferential processing of positive information), depressed individuals exhibit cognitive biases to mood-congruent information. These biases include sustained attention to negative information and a bias away from positive information (De Raedt & Koster, 2010, Duque & Vazquez, 2015), a bias for interpreting ambiguous information in a negative fashion (Everaert, Podina, & Koster, 2017; Wisco, 2009), and a bias for preferentially retrieving negative material from implicit (Gaddy & Ingram, 2014) and explicit memory (Matt, Vazquez, & Campbell, 1992), and they have been consistently found across studies. Importantly, the literature has shown that these information-processing biases appear to be closely interrelated.

It has been proposed that attentional biases toward negative information precede subsequent elaboration of such information, thereby fostering interpretation or memory biases (Everaert, Duyck, & Koster, 2014; Sanchez, Everaert, De Putter, Muller, & Koster, 2015). Experimental evidence has shown that the manipulation of early-stage attentional biases leads to differential patterns of elaborative processing (White, Suway, Pine, Bar-Haim, & Fox, 2011) that ultimately influence emotional regulation (Sanchez, Everaert, & Koster, 2016). In fact, Joormann and Vanderlind (2014) have proposed an evidence-based model of the interrelation between cognitive biases and their influence on the emotional regulation process in depression. As can be seen in Figure 1.3, the model posits that a biased attention towards negative information related to a specific event (e.g., difficulties to disengage from negative information) leads to interpretation and memory biases that affect the appraisal of the event, which, in turn, influence the emotional response. This biased processing, combined with cognitive control deficits associated with depression (e.g., executive control deficits), leads to the use of maladaptive emotional regulation strategies such as rumination (see Duque, Sanchez, & Vazquez, 2014; Whitmer & Gotlib, 2013), as well as impairs the use of adaptive emotional regulation strategies such as distraction or reappraisal (see Everaert, Grahek, Duyck, Buelens, Van den Bergh, & Koster, 2016; Joormann & Tanovic, 2015).

Figure 1.3. Cognitive biases and emotion regulation (Joormann & Vanderlind, 2014)



Therefore, current views of depression have proposed that depression and risk for depression are associated with a vicious cycle whereby negative mood states are maintained by sustained attention to negative information (Farb, Irving, Anderson, & Segal, 2015), which activates elaboration mechanisms and activation of negative self-schemas (Watkins & Nolen-Hoeksema, 2014). As this pattern becomes habitual, chronic low mood is maintained (Joormann & Vanderlind, 2014). In summary, it seems that how depressed people attend the world may affect subsequent elaboration of emotional information.

As the main entrance to the cognitive system and subsequent emotional processes, attention plays a crucial role in the etiology and maintenance of depression (Disner, Beevers, Haigh, & Beck, 2011). Therefore, a better understanding of biased attention is fundamental to not only describe the psychopathology of the disorder but also to develop new prevention and treatment strategies that may reduce the high burden and costs of depression.

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CHAPTER 2: LIMITATIONS OF CURRENT EYE-TRACKING ATTENTIONAL BIAS ASSESSMENT

Despite advanced and more direct measures used to assess attentional biases (i.e., eye-tracker paradigms), and the extant evidence of attentional biases in depression, these new paradigms are not exempt from methodological limitations. These limitations may restrict the reliability and the generalization of the results found. Therefore, in the next section, we will describe the main limitations of these paradigms that, from our point of view, should be accounted for when designing eye-tracking tasks.

2.1. Is there a real double attentional bias towards negative information and away from positive information?

Previous research has described the presence of a double attentional bias in depression. Depressed people tend to focus their attention towards negative information and away from positive information, regardless of the type of emotional stimuli processed (e.g., faces, words, images) -Armstrong & Olatunji, 2012; Peckhman et al., 2010. Yet, in most experimental paradigms and tasks used to assess attentional bias, participants' processing of stimuli is measured by comparing performance between emotional and neutral stimuli. Typically, in these studies an emotional stimulus (e.g. happy, sad or angry face) is paired alongside a neutral one thus competing for the participant's attention (see Duque & Vazquez, 2015; Sanchez et al., 2013).

Surprisingly, since the beginning of the study of visual attentional biases towards emotional stimuli in depression, no study has been specifically designed to analyze participants' deployment of attention when pairs of emotional stimuli (e.g., happy vs sad faces), rather than pairs of emotional and neutral stimuli, are presented alongside one another at the same time. Therefore, an unanswered question is what type of attentional bias, if any, might appear when opposing emotional stimuli (e.g., positive vs. negative information) are simultaneously presented.

Although some attentional studies have occasionally presented stimuli representing different emotions simultaneously in the same trial (see Leyman et al., 2011), specific analyses of attentional biases for each type of emotion have not been conducted. For instance, Kellough, Beevers, Ellis and Wells (2008) presented four different emotional images at the same time (i.e., happy, sad, threat and neutral images of people and unanimated objects), to a sample of clinically and never-depressed participants, finding that clinically depressed participants, compared to never-depressed participants, had a bias towards negative images and a bias away from the positive images. Other studies using this multiple presentation have also found similar results (see Sears, Thomas, LeHuquet, & Johnson, 2010).

Nonetheless, the design of these previous studies did not allow investigators to, specifically, analyze attentional performance for each type of emotional image displayed in the stimulus array. In contrast, in these tasks using different arrays of emotional and neutral stimuli, the deployment of participants' attention is unknowingly distributed throughout the different stimuli presented in the array. This methodological problem has made it difficult to develop or test specific hypotheses regarding attentional patterns when negative vs. positive information is presented simultaneously. As these types of co-occurrences (e.g., the simultaneous appearance of a positive and a negative word, or a sad and a happy face) are often found in real-life situations, it is important to know how healthy and depressed individuals react when facing these types of situations and clarify the attentional biases that emerge in these situations.

2.2. Psychophysical features of the stimuli: The case of teeth visibility in happy faces.

Attentional bias occurs for pictorial emotional stimuli (Ellenbogen & Schwartzman, 2009), emotional words (Koster, De Raedt, Leyman, & Lissnyder, 2010) and emotional faces (Joormann & Gotlib, 2007; Duque & Vazquez, 2015). However, in recent years, emotional faces have been preferentially used to assess attentional biases in depression for several reasons. First, the processing and recognition of facial expressions are critical components of social interactions and human survival (Darwin, 1872/1998). Following interpersonal theories of depression (Coyne, 1976), processing emotional faces is important in depression due to its relevance for interpersonal difficulties (e.g., peers rejection) that often characterize depression (Joiner & Metalsky, 1995). Second, the use of emotional faces facilitates the assessment of top-down cognitive processes due to the absence of semantic components that other stimuli posess (e.g., emotional words) – (Isaac, Vrijsen, Rinck, Speckens, & Becker, 2014). Thus, emotional faces seem to be particularly appropriate stimuli for the assessment of attentional biases in depression.

The processing of emotional faces requires decoding the emotional information contained in a face's structure (Ekman & Friesen, 1978). The extant evidence regarding emotional expressions processing has shown interesting findings that may influence the assessment of attentional biases using emotional faces. Indeed, empirical research on facial emotions has primarily focused on the processing of the eye area (which includes the forehead and eyebrows) and the mouth area (which includes the lips and cheeks) - (Ekman & Friesen, 1978; Smith, Cottrell, Gosselin, & Schyns, 2005). Yet, the depth of visual inspection for each of these areas may depend on which emotion is processed. For instance, Schurgin, Nelson, Iida, Ohira, Chiao, & Franconeri, (2014) found that a longer fixation time on the upper lip was characteristic of exploring joyful expressions while a longer fixation time on the eyes was characteristic of exploring sad faces. Additionally, the authors found that the frequency of fixation on each zone varied depending on the intensity of the emotion. In fact, when a joyful expression was reduced in intensity by minimizing the smile amplitude, the gaze fixations on the eye zone increased. This study suggests that the smile, a typical feature of happy faces, could draw attention to the mouth area. Thus, reducing the smile intensity might enable processing of other areas, such as the eye region, which are also important for emotional recognition.

In typical experiments of emotion recognition, an emotional face (e.g. depicting happiness) appears amongst an array of neutral faces to assess participant's speed and efficiency in its detection. Unfortunately, such studies have shown mixed results and the superiority (i.e., a faster detection) of some emotional faces over others remains unclear (for review see Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; and Shasteen, Sasson & Pinkham, 2014). For instance, the superiority of angry faces has been found in some studies (Hansen & Hansen, 1998; Fox & Damjanovic, 2006; Shasteen et al., 2014) while happy faces have shown an advantage in others (Purcell, Stewart, & Skov, 1996; Juth, Lundqvist, Karlsson, & Öhman, 2005; Becker, et al., 2011). Interestingly, Calvo and Nummenmaa (2008) found that the visual salience of teeth was the most important factor in explaining the initial orientation of gaze and speed of detection of different emotional expressions, including sadness, happiness, anger, fear, surprise, and disgust. The influence of teeth visibility has also been found in other studies of visual search strategy with faces depicting angry and happy expressions with open and closed mouths (Savage, Lipp, Craig, Becker, & Horstmann, 2013). These low-perceptual factors, which are often ignored, could explain the inconsistent findings of previous studies that have investigated the differential advantages of specific emotional expressions in detection of emotion tasks. In an attempt to systematically investigate the role that teeth visibility plays in the speed it takes to recognize happy and angry emotions, Horstmann, Lipp & Becker (2012) presented photographs of the same individuals showing those expressions with an open or closed mouth. When angry or happy faces were presented in a matrix of faces (i.e., the face in the crowd test), both expressions were more rapidly detected than neutral faces. The investigators attributed this result to differences in teeth visibility. Furthermore, this study showed that, when comparing the detection efficacy of angry vs happy faces, faster reaction times in correctly identifying the emotion were always associated with teeth visibility (i.e., emotional faces with open mouths were systematically identified faster than emotional faces with closed mouths). In summary, these findings support the notion that teeth visibility is a crucial component of facial emotion processing that provides processing advantages to the faces displaying that physical feature.

Despite the existing evidence demonstrating the influence of teeth visibility on the processing of emotional expressions, studies of attentional biases using faces as stimuli have not accounted for the potential impact of the salience of teeth on gaze patterns (Armstrong & Olantunji, 2012). For instance, studies utilizing free-viewing paradigms in which two emotional faces (e.g. happy versus a neutral expression) compete for a participant's attention have found that faster attentional orientation to happy faces emerges in both healthy controls and clinically depressed participants (Duque & Vázquez, 2015). However, it could be very well concluded that the attentional preference observed for happy faces could be due, in part, to the visual salience of teeth, which are typically visible in the happy faces used in this type of study. In fact, Calvo and Nummenmaa (2011) found that when a pair of faces (e.g. happy versus non-happy expressions) is presented at the same time in a forced-choice task, the salience of teeth in the happy faces is a critical factor for task efficiency. Therefore, attentional indexes used in eye-tracking studies to assess biased attention might be influenced by this "teeth visibility effect" leading to artificial conclusions based on the psychophysical properties of stimuli rather than on their intrinsic emotional characteristics.

To summarize, extant evidence on attentional performance in depression supports the need for analyzing biases towards positive and negative information concurrently in order to clarify the nature and the conditions in which this double attentional bias emerges. Further, attentional patterns to happy faces could be affected by the visual salience of low-level perceptual features associated with the smile rather than the processing of relevant emotional signals in this region (Calvo & Nummenmaa, 2008; Savage, et al., 2013).

Therefore, studies designed to assess attentional biases should consider the presentation of positive and negative information simultaneously and should systematically control for the influence of teeth visibility on attentional patterns.

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CHAPTER 3: EMOTIONAL STIMULI VALIDATION .[1]

As described in the previous chapter, research has shown that the teeth visibility of some emotional faces (e.g., happy and angry faces) can exogenously draw people's attention to those faces and may favor, for instance, faster recognition times (Horstmann, Lipp & Becker, 2012). As this process may interfere with the assessment of attentional biases to emotional information, this first study aimed to develop and validate the set of emotional faces (i.e., happy faces where teeth visibility is controlled) that would be used in the attentional bias assessment tasks described in the subsequent chapters of this dissertation.

Specifically, we aimed to assess the influence of teeth visibility of happy faces on their prototypicality (i.e., to what extent the model represents the typical prototype of the emotion depicted) and emotional intensity (Study 1). For this purpose, we created a set of happy faces with covered teeth (CT) and compared the ratings of prototypicality and emotional intensity between them and the same set of happy faces with normal teeth (NT). Specifically, two groups of participants separately rated the two sets of happy faces. One group judged a set of happy faces under normal visible teeth condition (NT) while the other group judged an identical set of pictures that had the teeth covered (CT). The design of the judgment task was based on the anchor-point procedure used in a previous study (Sánchez & Vázquez, 2013). Based on a similar pilot study (Horstman et al., 2012), which was focused on the role of teeth visibility, we hypothesized that scores for intensity and prototypicality would be higher for happy faces with NT than for CT faces.

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[1] Part of the information contained in this chapter corresponds to the published article:

Blanco, I., Serrano-Pedraza, I., & Vazquez, C. (2017). Don't look at my teeth when I smile: Teeth visibility in smiling faces affects emotionality ratings and gaze patterns. Emotion, 17(4), 640-647. doi: 10.1037/emo0000260

Additionally, we also aimed to explore visual patterns to NT and CT happy faces (Study 2). With this purpose, a free-viewing task was designed to assess participants' gaze patterns when the two happy faces (NT and CT) were simultaneously presented alongside one another. In this paradigm, both faces competed for participants' attention with no further instructions. It was expected that allowing participants to view the images with no further requirements would be the most adequate initial way to explore natural gaze patterns. As Geisler and Cormack (2011) suggested in their comprehensive review of methodologies available to study overt visual attention, free viewing tasks assume that "*gaze is attracted by image features that stand out perceptually in some way from the other image features*" (p.451). Therefore, a free viewing paradigm, that does not impose any predefined goal by the experimenter, seemed to suit our objective perfectly.

Teeth visibility has been found to be the most important factor explaining the initial orientation of gaze and provides advantages for the detection of some emotional expressions (e.g., happy faces) over others (e.g., neutral faces) – (Calvo & Nummenmaa, 2008). Further, previous studies have shown that when two different emotions (e.g. happy versus non-happy faces) are presented together, teeth visibility is the most relevant factor in discerning emotion (Calvo & Nummenmaa, 2011). Yet, a direct comparison of faces where teeth are selectively covered has not previously been performed. Therefore, as previous research has found that visible teeth draw participants' attention (Horstmann, Lipp & Becker, 2012), we hypothesized that the visual salience of teeth visibility of NT faces would draw and capture participants' attention. Specifically, we hypothesized that participants would have more automatic responses (i.e. first orientation and duration of first fixations) and would disproportionately maintain more of their attention (i.e. total time spent) looking at the mouth region in happy NT faces than in CT happy faces.

3.1. Study 1: Visibility of teeth and categorization of happy faces

3.1.2. Method

Participants. A total sample of 101 undergraduate students (12 male; 89 female), between the ages of 20 and 28, with a mean age of 22.5 years (*SD* = 1.9) volunteered to participate. The sample in the NT condition was comprised of 47 students (7 male; 40 female), between 21 and 28 years of age, with a mean age of 22.9 years (*SD* = 1.55). In the CT condition was 54 students (5 male; 49 female), between 20 and 27 years of age, with a mean age of 22.3 years (*SD* = 2.1). As this was the first study to assess prototypicality and emotional intensity when teeth visibility is controlled, we were unable to calculate the required sample size on the basis of prior studies. However, G-Power sample size analyses (one-way ANOVA fixed effects; α = .05; medium effect size = 0.4) yielded a minimum requirement of 84 participants (Erfelder, Fauily, & Buchner, 1996).

Materials

Psychological measures. A Scale for Mood Assessment (EVEA) (Sanz, 2001) was used to assess participants' current mood. This is a 16-item self-report instrument that uses an 11-point Likert scale ranging from 0 (*not at all*) to 10 *(very much*) to assess four different moods (sadness-depression, happiness, anxiety, and anger-hostility), each of which is comprised of four items. Internal consistency for each domain in this study was very good (sadness-depression, $\alpha = .91$; happiness, $\alpha = .93$; anxiety, $\alpha = .91$; and anger-hostility, $\alpha = .95$)

Stimuli. A total of 18 frontal-view faces with happy emotional expressions were selected from the A series of the Karolinska Directed Emotional Faces (KDEF) database (Lunqvist, Flykt, & Öhman, 1998). There were an equal number of male and female faces, and two versions (NT and CT) of each picture for the two different experimental conditions. In addition, a set of 18 neutral expressions from the same actor or actress was used in accordance with the anchor-point procedure.

To avoid any non-informative processing cues in the pictures, all were edited and cropped using Adobe Photoshop CS3. Images were converted to grey scale from their original coloured format and any surrounding, non-emotional features, such as the hair and neck were cropped (see Calvo and Lundqvist, 2008; Sanchez & Vazquez, 2013). All images were adjusted in size by fitting them into a grey square background (512 x 512 pixels). In the set of CT faces, teeth were covered using a 10-pixel Gaussian filter to smoothly blur the area where they were located (Aguado, Serrano-Pedraza & Garcia-Gutierrez, 2014; Valdes-Conroy, Aguado, Fernandez-Cahill, Romero-Ferreiro & Dieguez-Risco, 2014). All images were equated in contrast energy (Root Mean Squared Contrast, C_{RMS}=0.15; refer to equations 5-7 in Serrano-Pedraza, Goddard, & Derrington, 2007). See also Appendix B in Aguado, García-Gutierrez, & Serrano-Pedraza (2009).

Procedure. Assessment of NT compared with CT happy faces was completed by two independent samples of participants in different sessions. In each session, participants completed the EVEA before beginning the trials to account for the influence of their emotions on the assessment of faces. Following an anchor-point methodology (Sanchez & Vazquez, 2013) to ensure the accuracy of the evaluations, a happy face (either NT or CT, depending on the group) was paired with its corresponding neutral expression and presented side by side (see Figure 3.1.1). Each trial began with the presentation of the trial number for 2 s. Following that, each pair of faces (happy versus neutral) was displayed for 8 s. In each trial, participants were asked to rate on a 0-10 Likert scale (with 0 indicating "*not at all*", 5 indicating "*some*", and 10 indicating "*extremely*"), to what extent the happy face reflected the prototypical emotion of happiness (i.e., to what extent the emotional face adequately represents the emotion depicted, as compared to the neutral face,). Secondly, participants were also instructed to rate the face's emotional intensity using the same 0-10 Likert scale (i.e., in comparison to the neutral face, what level of emotional intensity is expressed by the emotional face). The advantage of this anchor-point procedure is that it allows participants to keep a comparison face (i.e., neutral) as a constant non-emotional reference point to which to compare the prototypicality and intensity of each happy expression. In having a constant point of reference (i.e., the neutral face of the same actor or actress), it is likely that random variations in categorization effects are minimized (see further details in Sanchez & Vazquez, 2013). Stimuli were presented with a beam projector on a 147 cm x 110 cm screen. The entire procedure lasted 10 min.

Figure 3.1.1. Example of a simultaneous presentation used in the anchorpoint validation study (in this case, covered teeth vs. a neutral face; KDEF model AF14)

3.1.3. Results

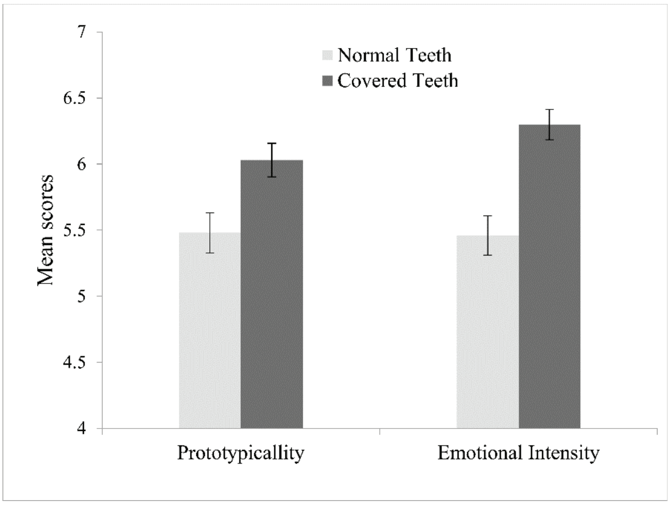
A series of one-way ANOVA were conducted to evaluate differences in current participant's mood between both groups of participants (NT and CT). The analysis showed no significant differences in depression (F (1, 99) = 1.13, p > .250), happiness (F

(1, 99) = .386, $p > .250$), anxiety (F (1, 99) = .673, $p > .250$), or anger-hostile mood (F (1, 97.94) = 3.277, $p = .069$) between NT and CT groups.

A series of one-way ANOVAs was carried out to compare total scores in prototypicality and intensity for both groups. Results showed that mean prototypicality of happy faces was significant lower in the NT condition ($M = 5.49$; $SD = 1.04$) than in the CT condition ($M = 6.03$; $SD = .94$); F (1, 99) = 7.53, $p = .007$, $\eta^2 = .07$. The intensity of the happy faces was rated lower in the NT condition ($M = 5.47$; $SD = 1.01$) than in the CT condition ($M = 6.30$; $SD = .85$); F (1, 99) = 20.40, $p < .001$, $\eta^2 = .17$ (see Figure 3.1.2).

Additional analyses were conducted to compare ratings of prototypicality and intensity for NT and CT faces with those found in a validation study by Sanchez & Vazquez (2013) to further investigate these unexpected results. The same anchor point method of our procedure was used to validate unmodified KDEF faces. A series of one-way ANOVA showed that participants' scores on NT faces did not differ in their mean prototypicality ($M = 5.49$, $SD = .83$) and mean intensity ($M = 5.47$, $SD = 1.11$) compared to the published validation data on prototypicality ($M = 5.25$, $SD = .99$) and intensity ($M = 5.20$, $SD = 1.01$), F (1, 34) = .510, $p > .250$ and F (1, 34) = .643, $p > .250$, respectively. Yet, Study 1 participants' scores in the CT condition were significantly higher than those found in the original validation data both on prototypicality ($M = 6.03$, $SD = .56$) and intensity ($M = 6.30$, $SD = .86$), F (1, 34) = 8.40, $p = .007$ and F (1, 34) = 12.38, $p = .001$, respectively.

Figure 3.1.2. Mean prototypicality and emotional intensity ratings of NT and CT faces.



Additionally, to test the anchor-point method reliability used in our study, Pearson correlation analyses between mean scores of prototypicality and intensity for both groups (NT and CT) were carried out. High correlations were found both for prototypicality ($r = .75$, $p < .001$) and for intensity ($r = .90$, $p < .001$) ratings.

Complementary analyses were carried out to assess the relationships between participants' current mood state in each of the four emotions assessed and their rating scores on prototypicality and intensity of the emotional faces. No significant correlations were found (all $p > .071$). Mean and standard deviation for intensity and prototypicality in both conditions (NT and CT) are shown in Table 3.1.1.

Table 3.1.1. Means and standard deviations for prototypicality and emotional intensity ratings in both face conditions (Normal Teeth and Covered Teeth happy faces).

	Prototypicality				Emotional Intensity			
	NT		CT		NT		CT	
KDEF Model	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
AF03	4.30	1.60	5.22	1.55	3.70	1.93	4.67	1.83
AF07	6.52	1.50	6.68	1.60	6.30	1.78	6.81	1.87
AF09	5.04	1.79	6.17	1.68	4.96	2.04	6.35	1.80
AF13	5.48	1.75	5.87	1.67	5.31	2.06	6.01	1.60
AF14	4.72	2.11	5.39	1.83	4.85	2.05	5.67	1.87
AF15	4.89	2.09	5.91	1.55	5.30	1.80	6.13	1.66
AF20	5.23	1.71	6.05	1.81	5.28	1.66	6.24	1.70
AF34	5.89	1.59	6.15	1.58	5.86	1.59	6.50	1.40
AF29	5.81	1.70	5.34	1.95	6.28	1.66	6.36	1.77
AM05	6.47	1.93	6.70	1.92	6.96	1.73	7.59	1.78
AM11	6.15	1.52	6.63	1.52	5.77	1.29	6.78	1.54
AM12	5.40	1.86	6.59	1.94	5.49	1.82	7.31	1.59
AM13	4.66	1.80	5.96	1.60	3.94	1.72	5.59	1.63
AM06	7.02	1.85	6.33	2.02	7.74	1.39	7.44	1.79
AM23	5.83	1.81	6.52	1.59	5.49	1.61	6.30	1.72
AM24	6.43	1.64	6.63	1.83	6.91	1.36	7.43	1.55
AM31	4.72	1.41	5.04	1.65	3.81	1.61	4.74	1.56
AM34	4.19	1.96	5.33	1.52	4.45	2.06	5.52	1.73

Note: NT = Normal Teeth face; CT = Covered Teeth face; AF = KDEF A-series Female model; AM = KDEF A-series Male model; M = Mean; SD = Standard Deviation

3.1.4. Conclusions.

There were significant differences between NT and CT happy faces on their prototypicality and intensity ratings. Yet, these differences were in the opposite direction to which was hypothesized (i.e., CT faces were scored as being significantly more intense and more prototypical of the happiness expression than NT faces). These results neither depended on the participants' mood prior to the rating procedure or on participants' judgements of the faces, as their ratings were similar to those found in a previous validation study (Sanchez & Vazquez, 2013).

Any plausible explanation of this finding should take into account the role of the visibility of teeth in the NT faces. Previous studies have shown that teeth could draw attention to this specific area (Horstmann, Lipp & Becker, 2012; Schurgin, Nelson, Iida, Ohira, Chiao, & Franconeri, 2014; Calvo & Nummenmaa, 2008, 2011; Savage, Lipp, Craig, Becker, & Horstmann, 2013), hindering the processing of information located in the eye region, which is highly relevant to emotional recognition (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). Thus, an eye-tracking study was designed to assess gaze patterns associated with both types of emotional faces (Study 2).

3.2. Study 2: Eye-tracking study

3.2.1. Method

Participants. A total of 38 students (18 males, 20 females) volunteered to take part in this study. The mean age was 24.87 years (SD = 5.12) and ranged between 19 and 42 years. Informed consent was completed before starting the experiment. All participants had normal or correct-to-normal vision. As in Study 1, this was the first eye tracking study where a NT face and a CT face were presented simultaneously in order to compete for participant attention. The number of participants was selected to make the study comparable with prior eye tracking studies of emotional faces (e.g., Calvo & Nummenmaa, 2011; Duque & Vazquez, 2015).

Materials

Stimuli and apparatus. The same 18 happy faces with two conditions (NT and CT) from Study 1 were used as stimuli in this eye tracking study. The images were presented on a 24” BENQ LCD monitor with a frame rate of 60 Hz. The luminance of the monitor was gamma corrected using a Minolta LS-110 photometer (Konica Minolta Optics, Inc., Osaka, Japan). The mean luminance of the monitor was 42.3 cd/m^2.

Participants’ eye movements and locations were measured and recorded at a frequency of 120 Hz (i.e. coordinates were recorded every 8.35 ms) using a Tobii tx-120 infrared eye tracker system. A distance of 60 cm between the eye tracker and the participants’ gaze was controlled with an anatomic chair that maintained their head in a comfortable and stable position. Before each session, a standard five-point calibration procedure was done. Stimuli presentation and eye tracker measurements were controlled with Tobii Studio software (2.0.6). The whole procedure was carried out in a sound proof room to avoid potentially distracting external stimuli.

Procedure. After signing and completing the informed consent, participants were seated in the anatomic chair, approximately 73 cm from the screen’s center at a horizontal visual angle of 14 degrees between the two pictures. Then, a free viewing task composed of 36 trials began. Each trial consisted of the presentation of a grey screen for 500 ms followed by a white cross fixation displayed in the center of the grey screen for another 500 ms. Then, a randomized white number (1 to 3 and 7 to 9) appeared in place of the cross for 1000 ms which participants needed to identify aloud as fast as possible. This procedure ensured participants’ central fixation at the beginning of each trial (Calvo & Avero, 2005). Immediately afterwards, a pair of happy faces (NT and CT) from the same actor or actress was displayed for 3500 ms. Participants were instructed to look at the faces freely without any constraints until the next trial. NT and CT faces were presented equally and their position on the screen (right or left side) was counterbalanced (see Figure 3.2.1). The experiment lasted for approximately 8 min.

Figure 3.2.1. Example of a simultaneous presentation of normal teeth versus covered teeth happy faces used in the eye tracking study (KDEF model AF14).

Selective attention measures. To analyze the pattern of gazes, two areas of interest (AOI) for each face were selected: the eye zone and the mouth zone. The eye zone included the region from the tip of the nose to the top of the forehead, while the mouth zone comprised the area from the tip of the nose to the bottom of the chin.

Three selective attention measures were extracted and analyzed for each AOI. These indexes were selected as they reflect significant processes described in models of orienting of attention (Posner, Rueda & Kanske, 2007):

- Firstly, Time to First Fixation (TFF) is the time elapsed between the appearance of stimuli and the occurrence of the first fixation on each AOI -a measure of the orientation bias to this AOI, which is also considered an index of attentional engagement.
- Secondly, First Fixation Duration (FFD) is the duration of the first fixation on each AOI, which is also a measure of attentional engagement (Duque & Vazquez, 2015).

- Finally, Total Fixation Time (TFT) is the average total time that participants spend looking each AOI across trials, which could be considered a measure of maintenance bias (Kellough, Beevers, Ellis, & Wells, 2008).

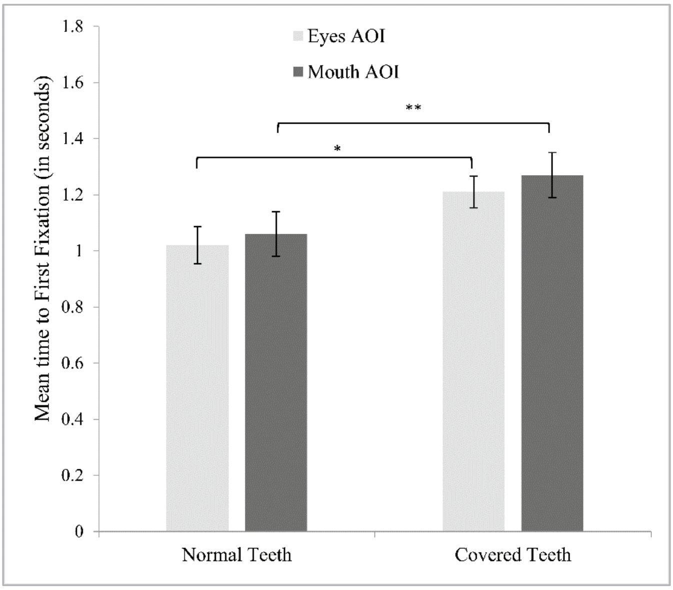
Visual fixations were defined as keeping one's gaze on a specific AOI on the screen for at least 100 ms and a maximum fixation radius of 1°, as employed in previous research (e.g., Bradley, Mogg, & Millar, 2000).

3.2.3. Results

A series of AOI (Eyes/Mouth) x Teeth (NT/CT) repeated measures within-subject ANOVAs was conducted on the three selective attention measures. Outliers, defined as ± 1.5 *SD*s for FFD (6 participants) and TFD (3 participants), were removed.

Time to first fixation (TFF). Analyses of TFF revealed a main effect of Teeth condition [$F\ (1, 37) = 10.88$, $p = .002$, $\eta^2 = .227$] and a significant AOI x Teeth interaction [$F\ (1, 37) = 4.46$, $p = .042$, $\eta^2 = .108$]. Bonferroni post-hoc tests revealed that there were no significant differences on TFF between both AOI (eyes/mouth) within each face, whether NT or CT. However, TFF was significantly faster for eyes in the NT condition than in the CT face. The same finding was observed in the mouth area (i.e. TFF was significantly faster in the NT face than in the CT face) (see Figure 3.2.2).

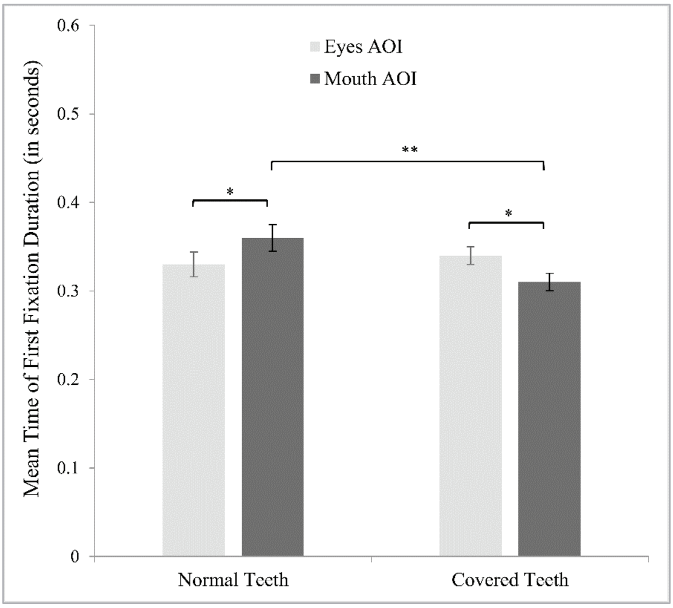
Figure 3.2.2. Mean Time to First Fixation to each area of interest (AOI) in both conditions (Normal and Covered Teeth happy faces).



Note: * = $p < .05$; ** = $p < .01$

First fixation duration (FFD). Results revealed a marginal main effect of teeth condition [F (1, 31) = 3.94, p = .056, η^2 = .113], and a significant AOI x Teeth interaction [F (1, 31) = 16.50, p < .001, η^2 = .347]. Bonferroni post-hoc tests showed that within each face, participants' first fixation in the NT faces lasted significantly longer at the mouth area than at the eye area. The opposite pattern was observed in the CT faces (i.e. participants had longer first fixation at the eyes area than at the mouth area). Furthermore, participants had a longer FFD at the mouth area of NT faces than at the mouth area of CT faces (see Figure 3.2.3).

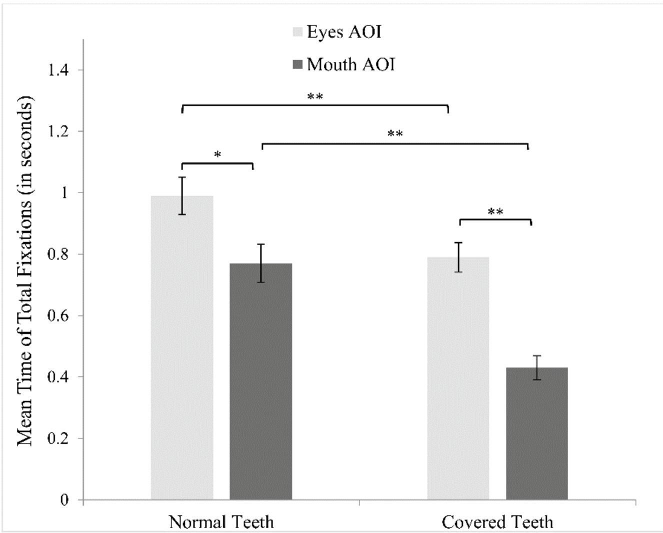
Figure 3.2.3. Mean time of First Fixation Duration for each AOI in both conditions (Normal and Covered Teeth happy faces).



Note: * = $p < .05$; ** = $p < .01$

Total fixation time (TFT). Analyses showed a main effect of AOI [F (1, 34) = 11.30, $p = .002$, $\eta^2 = .249$] and Teeth condition [F (1, 34) = 30.84, $p < .001$, $\eta^2 = .476$]. A significant AOI x Teeth interaction [F (1, 34) = 4.84, $p = .035$, $\eta^2 = .125$] was also found. Bonferroni post-hoc tests revealed that participants spent significantly more time looking at the mouth area of NT faces than at the mouth area of CT faces. The same pattern emerged for the eye area, where TFT was significantly longer on the eye area of NT faces than on the eye area of CT faces. Moreover, within both types of faces, participants showed a significantly longer TFT on the eye area than on the mouth area. To control for skewness in the distribution of data, logarithmic transformations were conducted for all time-related measures. Logarithmic ratios of TFT for each face (i.e. Log_{10} of the TFT on the eye area divided by Log_{10} of the TFT on the mouth area) were calculated to analyze the magnitude of the difference between the eye and mouth areas on each condition (NT and CT). Paired t-tests showed a marginally significant difference (t (17) = -2.09, p = .052) indicating that the eye to mouth ratio was higher in CT faces than in NT faces (see Figure 3.2.4).

Figure 3.2.4. Mean Total Fixation Time on each AOI in both conditions (Normal and Covered Teeth happy faces).



Note: * = $p < .05$; ** = $p < .01$

3.2.3. Conclusions.

Although participants did not show an automatic orientation of their attention to the mouth area of NT faces as hypothesized, the analyses revealed significant differences in the attentional engagement for both types of faces. Participants' first fixation was longer for the mouth area in NT faces than in CT faces. Furthermore, the duration of this first fixation lasted significantly longer on the mouth region than on the eye region in NT faces, while the opposite result was found in the CT faces.

The findings around total time spent viewing each AOI revealed that participants spent more time looking at the eye area compared to the mouth area, though this advantage was higher in the CT happy faces. These results are of interest, as previously, it may have been thought that as unusual perceptual objects, CT faces should draw relatively more attention when competing with NT faces. However, this was not the case. In fact, the mouth region in the NT happy faces engaged more of participants' attentional resources than the corresponding region in the CT happy faces.

3.3. General Discussion

With these two studies, we evaluated the specific influence of the presence or absence of teeth visibility in happy faces on the prototypicality and judgments of emotional intensity (Study 1) and the gaze patterns toward NT and CT happy faces (Study 2).

In Study 1, the unexpected enhanced estimation of prototypicality and intensity in the CT condition could be due to the possibility that when teeth are visible, participants direct their attention to the mouth area, which is less informative than the eye region to process the emotions of others (Baron-Cohen et al., 2001), in particular, happiness (Schurgin et al., 2014). The possibility that visual scanning patterns could differ in NT and CT faces was explored in Study 2. We predicted that participants would have a more automatic response to the NT happy faces, especially on the mouth region. Our results generally supported this prediction and suggest that NT faces automatically attract participants' first gaze. Once this happens, the time devoted to this first fixation will depend upon the regions of interest in each condition. Under normal conditions (NT faces), participants spent more time looking at the mouth area than at the eye area. Conversely, when teeth were not visible, their first fixation was longer on the eyes than on the mouth. These results emphasize the importance of the eye region in early stages of recognition of emotional faces (Peterson & Eckstein, 2012).

With regards to gaze maintenance, the results fully supported our hypothesis. In both types of faces, participants spent more time looking at the eyes than at the mouth. Yet, the preference for the eye area over the mouth area was greater in CT faces than in NT faces. That is, covering the teeth seemed to accentuate the processing of the eye region. Collectively, these results suggest that the processing advantage of happy faces (Savage et al., 2013) could be partly due to confounding effects related to the salience of physical characteristics. It could be possible that teeth visibility modifies both automatic components of attention (i.e. those related to initial orientation) as well as other components (e.g. total time spent looking at faces) in which more controlled strategies may intervene. Therefore, controlling teeth visibility seems to be relevant for studies aimed at evaluating attentional biases when happy faces are paired alongside other faces. Thus, future studies assessing attentional bias in either normal or clinical populations should be aware of the influence that some subtle physical or psychophysical properties of the stimuli may have.

Finally, the studies have some strengths and some limitations. The studies were designed to isolate teeth visibility as a specific component that may confound interpretations of the relative processing superiority observed in some emotions over others. The use of an eye tracking paradigm in the Study 2, as a behavioral measure, provides more robustness to the results. Further, that the pattern of results in Study 1 could not be explained by differences in participants' mood, a known factor that affects gaze preferences toward emotional faces (Sánchez, Vázquez, Marker, Lemoult & Joormann, 2013), or by participants' abnormal judgments on the intensity or prototypicality of the faces, support the reliability of the current findings. A limitation of the study was that prototypicality and intensity of emotional faces (Study 1), as well as the analysis of gaze patterns (Study 2), were conducted in two different (although similar) participant samples and used two different paradigms. Further, future studies should confirm if these results are also found in other emotions that have shown some processing advantages, such as anger (Horstmann, Lipp & Becker, 2012).

In any case, this study presents a novel approach to disentangle and control the role that different physical features may have in the perception of emotional faces and shed light on some factors that could explain the advantage of certain emotions. Our results suggest that some of these advantages may be a result of non-emotional factors that have been typically ignored in the existing research.

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CHAPTER 4: ATTENTIONAL BIAS ASSESSMENT.[1]

As described in Chapter 1, attentional biases are one of the main features of depression (Beck & Bredemeir, 2016). Indeed, depression is characterized by a double attentional bias to emotional information (i.e., an attentional bias to negative information and an attentional bias away from positive information) – (Duque & Vazquez, 2015). However, no study has ever been designed to analyze attentional patterns in depressed participants when positive and negative information (e.g., happy vs. sad faces) are presented simultaneously. In addition, there are no studies that compare the attentional processing of these types of trials (i.e., happy vs. sad faces) with the attentional processing of the typical trials used in previous research (i.e., happy vs. neutral; or sad vs. neutral faces). These types of studies are necessary to disentangle the double attentional bias that occurs when several types of emotional information are presented concurrently.

Therefore, the aim of this study was to analyze the attentional performance of dysphoric and non-dysphoric participants when processing pairs of emotional stimuli as compared to their processing of pairs of emotional and neutral stimuli. For this study, happy and sad faces were selected as emotional stimuli as there is ample evidence showing specific attentional biases associated with these stimuli in depressed participants. Additionally, as previous research has shown that low-level psychophysical properties of emotional faces (e.g., luminance and visibility of the teeth)

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[1] Part of the information described in this chapter corresponds to the under review article:
Blanco, I., Poyato, N., Nieto, I., Boemo, T., Pascual, T., Roca, P., & Vazquez, C. Attentional biases in dysphoria when happy and sad faces are simultaneously presented. *Cognition & Emotion* (under review)

may affect attentional patterns (Blanco, Serrano-Pedraza, & Vazquez, 2017), these factors were systematically controlled in this study.

Although different emotional expressions (i.e., happy, sad, angry and neutral faces) have been presented simultaneously in the same trial in previous studies (Leyman, De Raedt, Vaeyens, & Philippaerts, 2011), to our knowledge, this is the first study that attempts to assess the attentional biases of dysphoric and healthy participants when happy and sad faces are presented at the same time with no other distractors (i.e., other emotional expressions presented in the same trial). Further, this is also the first study that systematically controls the influence of teeth visibility of happy faces when assessing attentional biases.

We first hypothesized that dysphoric participants, compared to healthy participants, would show a significantly less attentional bias towards happy faces, regardless of whether these faces were presented simultaneously with sad or neutral faces. Additionally, based on the gradient hypothesis (Everaert, Duyck, & Koster, 2014), we hypothesized that biases would be significantly higher in individuals with high levels of dysphoria than in healthy participants and individuals with low levels of dysphoria. All of these hypotheses assumed, based on previous research (Armstrong & Olatunji, 2012), that differences between groups would be significant in late processing stages (i.e., the total time that participants spend looking at emotional information) but not in initial orientation biases.

4.1. Method

Participants

A sample of 151 volunteer undergraduate students participated in the study. Participants received a monetary compensation (10 euros) or course credit in exchange for their participation. Nine participants (5.96%) were not included in the final analysis due to poor eye-tracking quality (defined as having less than 80% of the eye-tracking signal on more than one third of the trials; Raila, Scholl & Gruber, 2015).

Using Dozois, Dobson and Ahnberg (1998) cutoff scores of the Beck Depression Inventory II (Beck, Steer & Brown, 1996) for undergraduate samples, participants were distributed into three groups. 84 participants comprised the non-depressed group (ND; BDI-II scores ranging from 0 to 12), 39 participants comprised the mild-dysphoric group (MD; BDI-II scores ranging from 13 to 19), and 19 participants comprised the high-dysphoric group (HD; BDI-II scores ranging from 20 to 63).

Materials

Self-report measures

The Beck Depression Inventory-II (BDI-II; Beck, Steer & Brown, 1996) was used to evaluate depressive symptoms of the sample. BDI-II is a 21-item self-report inventory. Each item has four statements ranging on a 0 to 3 scale. The internal consistency of our sample was very good (α = .88).

Experimental stimuli

Stimuli were a set of 36 emotional faces (18 happy, 18 sad) and their corresponding 18 neutral faces from the same actress/actor. Stimuli were selected from the Karolinska Directed Emotional Faces database (KDEF – Lundqvist, Flykt & Ohman, 1998). All emotional faces were frontal-view pictures, and there was the same number of female and male faces (9 female, 9 male). Non-informative areas surrounding the faces (i.e., neck, ears, and hair) were cropped and all pictures were converted to grey scale. To control the influence of the stimuli luminance and the teeth visibility of happy faces on participants' attention, all the stimuli were equated in contrast energy and the teeth were blurred using a grey Gaussian-type filter (see Blanco, Serrano-Pedraza & Vazquez, 2017).

Apparatus

A Tobbi Tx-120 eye tracker was used to record participants' gaze patterns at a frequency of 120Hz. A five-point calibration was done. The distance between participants' eyes and eye tracker was, approximately, 60 cm. Furthermore, the stimuli presentation was controlled by Tobbi Studio software (2.0.6) and all the stimuli were presented on a 24" LCD monitor (frame rate 60Hz). Additionally, to control the luminance of the screen, the monitor was gamma corrected (mean luminance 42.3 cd/m2).

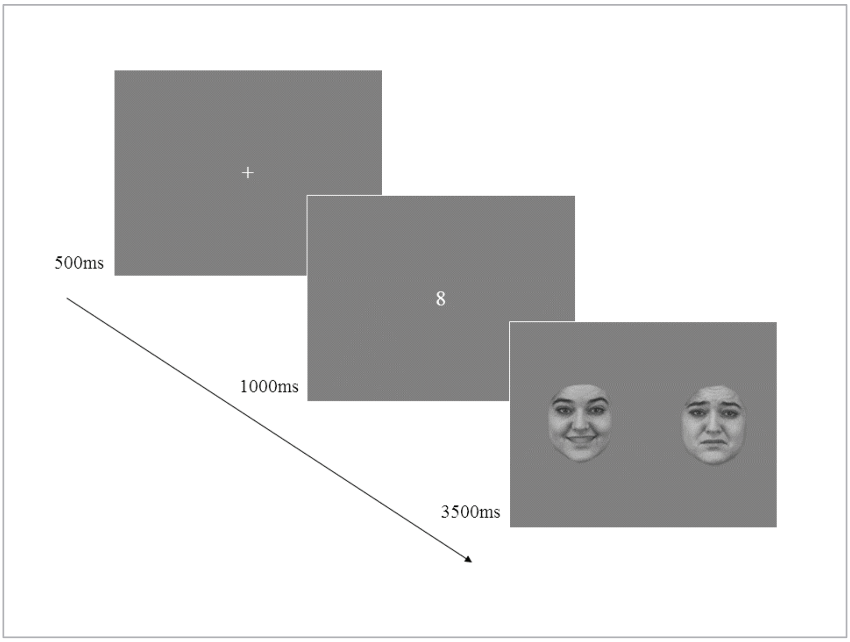
Attentional Task

The task consisted of 108 trials with pairs of faces (36 happy vs. neutral, HN; 36 sad vs. neutral, SN; and 36 happy vs. sad, HS). In each trial, one face appeared on the right and the other on the left side of the screen (14º horizontal visual angle between the two images) competing for participants' attention. The position of each face was counterbalanced, and each face was presented the same number of times. Each trial began with a grey screen (500ms) followed by a white fixation cross in the center of the screen (500ms). To ensure that participants were looking at the center of the screen, a random number appeared replacing the fixation cross (1000ms) and participants were instructed to say it aloud as quickly as possible (Calvo & Avero, 2005). Thereafter, a pair of faces was displayed (3500ms). Participants were asked to freely look at the faces without any further instruction until the next trial (See Figure 4.1).

Procedure

In a soundproof room, participants read and signed the informed consent form and then filled out the Beck Depression Inventory-II. Afterwards, participants completed the attentional task. The entire session lasted approximately 20 minutes.

Figure 4.1. Attentional biases assessment task. Example of an HN condition



Data filtering and attentional measures

Following Raila, Scholl and Gruber's method (2015), eye-tracker reliability signal was defined as the percentage of time that participants spent looking and making saccades (i.e., dwell-time) within the screen area during the presentation of the stimuli in each trial. Thus, dwell-time on the entire screen for each trial was calculated and analyzed as a relative percentage of the stimuli duration (3500ms) for each participant. Then, only those participants with more than 80% of the time looking and making saccades at the screen area on more than two thirds of the trials were included in the analysis.

Three attentional measures were extracted to analyze the attentional processing of emotional information at different temporal stages. First Fixation Latency (FFL; i.e., time elapsed between appearance of the stimuli and the first fixation on each type of face in each trial) and First Fixation Duration (FFD; i.e., duration of the first fixation made on each type of face in each trial) were interpreted as measures of early stages of attentional processing. Total Fixation Duration (TFD; i.e., total time spent looking at each type of face in each trial) was interpreted as a measure of later stages of attentional processing. Additionally, relative bias scores were calculated for each attentional measure on each type of trial (Duque & Vazquez (2015). These bias scores were calculated by subtracting the value obtained for the neutral face from the value obtained for the emotional one on the (HN and SN trials). In the HS trials, the bias score was calculated by subtracting the value obtained for the sad face from the value obtained for the happy face. These bias scores were used to analyze specific biases regarding to each pair of faces. A positive value on the HN and SN conditions indicates a bias to the emotional face (i.e., a bias to the happy or the sad faces, respectively), while a positive value on the HS condition indicates a bias to the happy face.

4.2. Results

Group characteristics

Demographic information and depression scores are shown in Table 4.1. There were significant group differences in depression [F (2, 141) = 348.9, p < .001; η^2 == .83], and sex [X^2 (2, n = 142) = 6.19; p = .045], but not in age [F (2, 141) = 2.4, p = .096].

Table 4.1. *Differences in Demographic and group characteristics.*

	ND (N = 84)	MD (N = 39)	HD (N = 19)
	M *(SD)*	M *(SD)*	M *(SD)*
BDI-II	5.78 (*2.99*)	15.41 (*2.11*)	27.7 (*6.42*)
Age	21.2 (2.*53*)	20.5 (*1.9*)	20.2 (*2.27*)
Female (%)	70.2	87.2	89.5

Notes. ND = Non-dysphoric group; MD = Mild-dysphoric group; HD = High-dysphoric group; *M* = Mean; *SD* = Standard Deviation; BDI-II = Beck Depression Inventory–II.

Relationship between depression scores and attentional biases to emotional information

A series of zero-order correlations were calculated to analyze the association between depression scores and attentional biases. Correlations were calculated for the three types of trials (HN, SN, and HS) and for each attentional index.

Results showed that depression scores were not related to early stages of attentional processing (i.e., FFL and FFD) on any type of trial (all p > .65). However, depression scores were negatively associated with TFD bias to happy faces in the HN condition (r = -.363, p < .001) and the HS condition (r = -.332, p < .001). (See Table 4.2)

Table 4. 2. Correlations between attentional indexes and depression scores for each type of trial.

	Depression scores (BDI-II)
First Fixation Latency	
Happy vs. Neutral	-0.155
Sad vs. Neutral	0.004
Happy vs. Sad	-0.152
First Fixation Duration	
Happy vs. Neutral	0.033
Sad vs. Neutral	0.151
Happy vs. Sad	0.004
Total Fixation Time	
Happy vs. Neutral	-0.363***
Sad vs. Neutral	0.145
Happy vs. Sad	-0.332***

Note. BDI-II: Beck Depression Inventory-II; *** = $p < .001$

Attentional biases to emotional information

A series of 3 (Group: ND, MD, HD) x 3 (Type of trial: HN; SN; HS) ANCOVAs (controlling for sex) were carried out to assess differences between groups in attentional biases to emotional information.

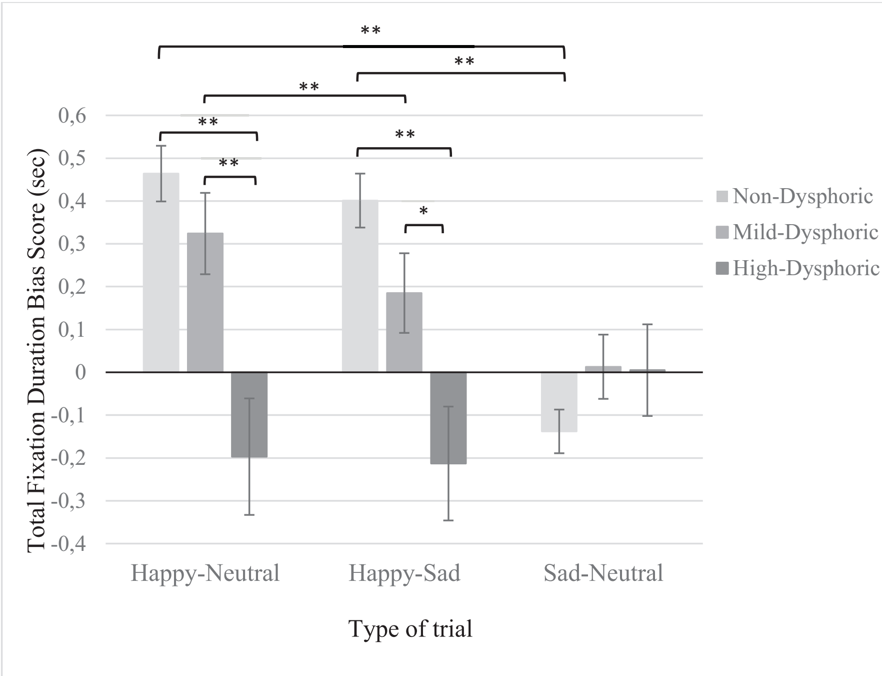
Analysis of attentional biases during initial stages of attentional processing

- *First fixation latency.* Results showed no significant main effects (group F (2, 138) = 2.76, p =.07, η^2 = .038; type of trial F (2, 276) = 1.26, p = .285) or interaction (group x type of trial F (4, 276) = .750, p = .559).
- *First fixation duration*. Similarly, there was no significant main effects (group F (2, 138) = .002, p =.961; type of trial F (2, 276) = .252, p = .777) or interaction (group x type of trial F (4, 276) = .373, p = .828).

Analysis of attentional biases during late stages of attentional processing

- *Total fixation time*. Results showed a non-significant main effect of type of trial F (2, 276) = .901, p = .408. However, a significant main effect of group F (2, 138) = 9.14, p < .001, η^2 = .117 was found. This main effect was qualified by a significant group x type of trial interaction F (4, 276) = 6.306, p < .001, η^2 = .084 after controlling for sex. Bonferroni post-hoc tests showed that HD participants spent significantly less time viewing happy faces (in both the HN and HS conditions) than ND and MD participants (all p < .045). Furthermore, ND participants spent significantly more time viewing happy faces (in the HN and HS conditions) than neutral faces in the SN condition (both p < .001). There were no significant differences in the time that ND participants spent looking at happy faces in the HN and HS conditions. Regarding MD participants, they spent significantly more time viewing happy faces in the HN condition than in the HS one (p = .029) but there were no significant differences found in their performance on the other types of trials. Finally, with regard to the HD group, there were no significant differences between any types of trials (all p > .07). (See Figure 4.2).

Figure 4.2. *Attentional biases on total fixation duration for emotional and neutral faces within different types of trials (HN, HS, SN).*



Note. * = $p < .05$; ** = $p < .01$. Positive scores reflect a bias towards the first element of the pair of stimuli (H-N, H-S, S-N) whereas negative scores reflect a bias towards the second element of the stimulus pair.

4.3. Discussion

The aim of the present study was to examine whether attentional biases towards positive or negative faces in dysphoria emerge not only when these emotional faces are processed in the presence of neutral faces but also when positive and negative faces are presented together in the same trial.

Our first hypothesis was that dysphoric participants, as compared to non-dysphoric participants, would show a reduced bias towards happy faces regardless of the type of accompanying stimuli (i.e., sad or neutral faces). Our results partially confirmed this hypothesis. Non-dysphoric participants (ND) spent significantly more time looking at happy faces when they were paired with either neutral or sad faces. Furthermore, this pattern was significantly different to the one found in participants with high levels of depressive symptoms (HD). Instead of attending more to positive stimuli, HD participants showed the reverse gaze pattern (i.e., a tendency to look away from happy faces under any other accompanying face stimulus) – see Figure 1. Mild-dysphoric participants (MD) showed a similar pattern to that of ND individuals (i.e., attending more to happy faces than to sad or neutral ones). Yet, while the MD group also had a bias towards happy faces like the ND group, this difference was smaller and did not reach statistical significance.

In regard to differences in the processing of happy faces when accompanied with a neutral face versus a sad face, which was the main aim of our study, our results offered a similar pattern of results. Yet, we also found an important exception. As it can be seen in Figure 1, the processing of happy faces competing with sad faces (which has been unexplored in the current literature of emotional processing) results in a greater difference between the MD group and the ND group than did the processing of happy faces competing with neutral faces. Although this difference did not reach statistical significance, the MD group tended to look less toward the happy faces in the HS condition than it did in the HN condition. Interestingly, the HD group did show a mood-congruent bias consisting of looking less towards happy faces under any circumstance (i.e., when accompanied by a neutral or a sad face). In other words, it seems that the HS condition enhances the probability of finding differences between dysphoric and healthy participants more than the typical happy-neutral condition.

Our results partially supported the gradient hypothesis (see Fig 1), which was confirmed by a significant negative correlation, for the HN and HS trial types, between depression scores and the magnitude of the bias towards happy faces. Participants with higher levels of depression showed a higher maintenance attentional bias away from happy faces in both the HN and HS condition.

Although, according to our results, the use of positive stimuli seems perfectly adequate to elicit biases associated with depression (Winer & Salem. 2016), it must be noted that pairs of sad-neutral faces did not yield any significant bias in any of the groups. The non-dysphoric group showed a tendency to look away from the sad face, but this bias did not reach statistical significance. However, similar studies with clinical populations have shown that depressed participants have a bias towards sad faces when they are accompanied by neutral ones (Duque & Vazquez, 2015).

Future studies, using clinical samples or a wider range of severity scores in depression, would be very helpful to clarify whether depressed patients are more sensitive to competing antagonist emotional stimuli. In fact, meta-analytic evidence shows that individuals meeting diagnostic criteria for major depressive disorder have a more robust maintenance bias for negative stimuli than individuals classified as dysphoric based on a cut-off score in a symptoms behavioral measure (Armstrong & Olatunji, 2012). Finally, in line with previous findings (Armstrong & Olatunji, 2012), differences in attentional performance emerged only in total time fixation indexes but not within orienting indexes, which are more sensitive to the more automatic stages of attentional processing.

In summary, attentional biases towards positive information are apparent when positive information is presented with both neutral and negative information, and only in late stages of attentional processing. Thus, it seems that the capacity of positive information to activate biases of processing is quite robust under a variety of experimental stimulus settings. Furthermore, the finding that studies which require participants to process positive and negative information simultaneously may enhance differences between groups should be considered in future research.

The study has some strengths and limitations. Firstly, to the best of our knowledge, this is the first study that assesses attentional biases in depression when two emotional stimuli that represent antagonistic emotions are presented simultaneously and have to compete for the participants' attention. Furthermore, this is also the first study that systematically controls teeth visibility of happy stimuli when assessing attentional biases. Regarding the limitations, the cross-sectional nature of the present study does not allow us to make any inferences about the causal implications of the results. Moreover, dysphoria was only measured with an inventory of symptoms of depression but there was neither a clinical diagnosis using a structured interview nor any information on past episodes of depression. As other studies have shown, participants with past history of depression may still show cognitive biases of emotional information (Sears, Newman, Ference & Thomas, 2011). Lastly, the study only included one type of negative stimuli—sad faces. As there is some controversy about whether other negative emotional faces (e.g., anger) may also elicit attentional biases in depressed participants (Gotlib, Krasnoperova, Yue & Joormann, 2004; Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013), further research should explore whether different pairs of emotional stimuli, other than the HS pairs, are capable of eliciting specific biases linked to depression.

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CHAPTER 5: MODIFICATION OF ATTENTIONAL BIASES IN DEPRESSION[1]

As described in the first chapter of this dissertation, depressed individuals seem to be characterized by a double bias in their deployment of attention (i.e., sustained attention to negative stimuli and reduced attentional engagement and maintenance of attention to positive stimuli) - (Duque & Vazquez, 2015; Armstrong & Olatunji, 2012). If such attentional biases play a causal role in the etiology and maintenance of depression (Gotlib & Joormann, 2010), and remain stable even when depressive symptoms decrease (Sears, Newman, Ference, & Thomas, 2011), then their correction should promote recovery from the disorder and prevent relapses. A new set of cognitive techniques, known as Attentional Bias Modification (ABM), have been developed to modify attentional biases in emotional disorders.

5.1. Correcting attentional biases in depression

In a seminal experiment, MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, (2002) randomly assigned healthy participants to receive attentional training designed to direct their attention either toward or away from threat-related words. The training procedure was an adaptation of the dot-probe paradigm for measuring attentional bias for threat (MacLeod, Mathews, & Tata, 1986). The authors modified this paradigm to train attention away from threat by having the dot repeatedly replace

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[1] Part of the information described in this chapter corresponds to the published article:

Vazquez, C.*, **Blanco, I**.*, Sanchez, A., & McNally, R. J. (2016). Attentional bias modification in depression through gaze contingencies and regulatory control using a new eye-tracking intervention paradigm: study protocol for a placebo-controlled trial. BMC Psychiatry, 16(1), 439. doi: 10.1186/s12888-016-1150-9. (*Equal contributors) neutral words and toward threat by having it repeatedly replace threatening words. As in the attentional assessment dot-probe task, participants had to detect the location of the dot as soon as possible. After the training, participants were exposed to a laboratory stressor. The authors found that the group trained to attend to neutral stimuli was significantly less emotionally reactive to the stressor than the group trained to attend to threat stimuli. The researchers concluded that attentional bias for threat heightens anxiety proneness, and that reducing such bias diminishes anxiety proneness (MacLeod et al., 2002). This experiment inspired the development of ABM procedures as well as provided evidence indicating the causal effects of cognitive processes on emotion (Hertel & Mathews, 2011; MacLeod & Mathews, 2012).

Because of their conceptual appeal (i.e., the possibility of changing emotions through pure cognitive interventions), their reduced costs and their acceptability, ABM procedures have been proposed as valuable clinical tools (Bar-Haim, 2010; MacLeod & Mathews, 2012). Yet, in the field of depression, only a few ABM studies have been conducted with clinical samples (Baert, De Raedt, Schacht, & Koster, 2010; Browning, Blackwell, & Holmes, 2012, Beevers, Clasen, Enock, & Schyner, 2015), with most of these studies involving participants scoring high on questionnaire measures of depression (Haeffel, Rozek, Hames, & Technow, 2012; Kruijt, Putman, & Van der Does, 2013; Tsumura, Shimada, Nomura, Sugaya, & Suzuki, 2012; Wells & Beevers, 2010; Yang, Ding, Dai, Fang, & Zhang, 2014). Some of these studies have found that either attentional biases, depressive symptoms, or both, can be modified using ABM procedures. For instance, Tsumura et al., (2012) trained dysphoric participants to look away depressed-related words using a modified dot-probe task. In this study pairs of words (one depressed-related word and one neutral word) were presented to the participants. In the experimental condition, the dot followed the neutral word in 94% of the cases, whereas in the control condition the dot replaced both words the same amount of times. The assessment of attentional biases before and after the treatment was performance on a classical dot-probe task. The authors found that, compared to the control participants, the experimental group showed a reduction of the attentional bias towards depressed-related words after the training. This change in attentional biases was followed by a decrease of dysphoric mood after the ABM procedure, but only for the high-dysphoric participants (Tsumura et al., 2012). Similarly, Wells & Beevers (2010) conducted an ABM study where participants were trained (during 4 ABM sessions) to avoid sad faces through a modified dot-probe task. The authors found that although the trained participants, compared to control participants, showed less attentional bias after the ABM procedure, there were no differences between groups in depressive symptoms after the training. However, the trained participants showed a greater reduction of depressive symptoms in a 2-week follow-up. Further, this improvement of depressive symptoms was mediated by the changes in attentional biases (Wells & Beevers, 2010).

Nonetheless, other ABM studies in depression have found non-significant or inconclusive results. For example, Kruijt et al., (2013) trained dysphoric participants, in a single-session ABM procedure, to locate happy faces in an array of disgusted faces. However, the authors did not find any significant change in either attentional biases or positive and negative mood after the ABM procedure (Kruijt et al., 2013). The same absence of attentional and mood changes was found by Baert et al., (2010 – Study 2) in a clinical sample. However, these authors (Baert et al., 2010 – Study 1) found that after an ABM procedure, a sample of dysphoric participants showed changes in depressive symptoms although these changes were not preceded by changes in attentional biases.

Therefore, studies of ABM efficacy in emotional disorders have yielded inconsistent results (for a review see Duque, Lopez-Gomez, Blanco, & Vazquez, 2015).

In fact, some meta-analyses have found moderate or large effects sizes for change in attentional bias after ABM (Beard, Sawyer, & Hofmann, 2012; Hakamata et al., 2010), whereas others have found small effect sizes (Cristea, Kok, & Cuijpers, 2015; Mogoaşe, David, & Koster, 2014). Similar inconsistency has been found for symptom improvements after training. Medium effect sizes have been found in some meta-analyses (Hakamata et al., 2010), whereas small effects sizes were found in others (Beard et al., 2012; Hallion & Ruscio, 2011). In a more refined meta-analysis, which specifically focused on ABM in distinct clinical conditions (i.e., anxiety, depression, and substance abuse) – (Mogoaşe et al., 2014) concluded that attentional biases and symptom changes were successfully reduced in anxiety (both in clinical and healthy samples) although the average effect size was small. Yet, the authors did not find significant changes for other clinical conditions, such as depression. A similar negative conclusion was reached in a recent meta-analysis on Cognitive Bias Modification (CBM) procedures in anxiety and depression (Cristea et al., 2015). Although this meta-analysis did not separate the results according to the different types of training procedures used (e.g., interpretation bias training as opposed to ABM), as in the Mogoase et al.'s (2014) meta-analysis, their conclusions were rather pessimistic regarding the utility of CBM procedures. In the case of depression, the moderate significant effect sizes found when comparing normal controls to subclinical samples ($g = 0.43$) or clinical samples ($g = 0.33$) disappeared when outliers and publication bias were considered. The authors of this meta-analysis concluded that CBM is not as promising of an intervention as many had hoped (MacLeod & Mathews, 2012).

Therefore, although some initial positive findings regarding the use of ABM led some authors to propose it as an alternative treatment for emotional disorders (Bar-Haim, 2010; MacLeod & Holmes, 2012), some discordant voices (Emmelkamp, 2012) and subsequent meta-analyses (Cristea et al., 2015; Mogoaşe et al., 2014) have reduced the enthusiasm of those previous claims.

5.1.2. Conceptual and methodological limitations of ABM procedures

One possible explanation for the discrepancies in the literature regarding ABM and the modest effect sizes it has produced is that current experimental procedures to correct biases are suboptimal. Cristea et al.'s meta-analysis (Cristea et al., 2015) concluded that the procedural diversity of CBM studies may render meta-analysis premature. They recommended that researchers focus on developing high quality trials sufficiently powered. Yet it is also plausible that limitations of current methods, such as unreliability of the dot-probe paradigm (Cisler, Bacon, & Williams, 2009) or the failure of researchers to properly distinguish between different aspects of attention (e.g., engagement, disengagement) - (Armstrong & Olatunji, 2012) means that there is still room for significant methodological and conceptual improvements in current suboptimal ABM procedures (Koster & Bernstein, 2015). ABM techniques should be rooted in advancements in both basic and clinical science, and should target specific processes (e.g., gaze behavior) associated with specific attentional biases characterizing each type of disorder. More specifically, new ABM methods in depression should address the issues described below.

5.1.2.1. Trial-by-trial feedback

Most of the extant ABM tasks, such as the modified dot-probe task, are very repetitive (Mogoașe et al., 2014). These procedures are based on a model of automatization as a way to modify cognition (Wadlinger & Isaacowitz, 2011). ABM training typically consists of hundreds (Kruijt et al., 2013; Wells & Beevers, 2010), or thousands (Browning et al., 2012; Yang et al., 2015), of repetitive trials performed over a time period of one single session (Haeffel et al., 2011; Kruijt et al., 2013) to several weeks (Baert et al., 2010; Wells & Beevers, 2010; Yang et al., 2015). ABM is consequently very tedious which may impair the efficacy of cognitive training. In fact, patients report that ABM is less interesting than other CBM procedures such as interpretation bias modification training (Beard et al., 2012). Improvements in ABM procedures that render them more motivationally engaging for patients, such as performance feedback and reward, are desirable as such changes may foster more robust changes (Bjork, Dunlosky, & Kornell, 2013). It is surprising that in standard CBM and, more specifically, ABM procedures, participants do not get feedback on their performance (e.g., speed, correctness of their responses, etc.) and advancing from one trial to another is not based on a performance criterion but rather on the mere passing of time (i.e., the stimulus duration of each trial). Thus, the implicit model of learning is based on a mechanical repetition of trials to engage or disengage from a certain type of stimulus (Amir, Kuckertz, & Strege, 2016). Yet, this approach does not take advantage of the role of reward in learning and attentional processes and has the risk of increasing boredom and decreasing attention (see Smith et al., 2006).

The anticipation of reward or receipt of reward upon performance shapes visual selective attention strategies (Chelazzi, Perlato, Santandrea, & Della Libera, 2013). Thus, one possible way of optimizing participants' attentional performance in ABM paradigms could be providing trial-by-trial feedback on performance (Donohue et al., 2016). For example, in a recent study testing ABM through reward (Sigurjónsdóttir, Björnsson, Ludvigsdóttir, & Kristjánsson, 2015), the authors used a dot-probe paradigm with disgust and neutral faces in a sample of clinically anxious participants. For each trial, participants received an auditory signal following correct responses plus feedback on how much money they were earning. The results showed that the six-session ABM training significantly improved the participants' attention towards neutral faces, although it did not reduce anxiety symptoms.

5.1.2.2. *Targets of attentional training and training procedure: eye-tracking methodology.*

In the case of anxiety, there is evidence that anxious individuals show increased attention to threatening stimuli at early stages of information processing and then, at later stages, they tend to avoid threat (Cisler & Koster, 2010). This vigilance-avoidance pattern is not shown in depression. On the contrary, from a time-based perspective, in the case of depression most attentional biases occur not at early stages of processing but at late stages. However, ABM studies on depression have used modifications of reaction time paradigms derived from ABM procedures used in anxiety disorders (Duque et al., 2015). In particular, most of the existing literature on ABM in depression has used variations of the modified dot-probe task, following the initial procedure developed by MacLeod et al. (1992). Serious concerns about the reliability of the dot-probe paradigm

(Cisler, Bacon, & Williams, 2009) may render it unsuitable for ABM except under specific conditions (Price et al., 2015; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014).

Even more importantly, the dot probe task does not allow the identification and differentiation of precise time-based components of attentional performance (i.e., attentional engagement, maintenance, and disengagement) - (Posner, 1980) that are especially relevant for depression (Armstrong & Olatunji, 2012). ABM procedures in depression should be directed toward modifying later components of attention as these are the most affected in depression (Armstrong & Olatunji, 2012; Sanchez, Vazquez, Marker, Lemoult, & Joormann, 2013). Further, given the double attentional bias in depression (Duque & Vazquez, 2015; Kellough, Beevers, Ellis, & Wells, 2008), ABM in depression should target both biases (i.e., increasing attention to positive stimuli while reducing attention to negative stimuli). That is, ABM should be aimed at reducing the time it takes to disengage from negative information, and increasing the maintenance of attention to positive information once attention has been captured by these positive features.

Therefore, eye-tracking paradigms may serve to not only assess attentional biases and distinguish relevant attention processing stages but also to adequately target and modify attentional biases.

5.1.2.3. Assessment of transfer effects to emotional functioning and symptoms.

Another important methodological consideration refers to the detection of transfer effects after receiving ABM training. It is possible that outcomes of ABM procedures are not immediately detectable or they may appear only under specific circumstances (Scher, Ingram, & Segal, 2005). A study using dot-probe training with either positive faces or positive words (Browning et al., 2012) found that the face ABM modality was ineffective in reducing depressive symptoms in patients whose depression had remitted at the time of training but after 4 weeks participants showed a significant reduction of symptoms. The authors interpreted their results in terms of the possibility that ABM training might have reduced the vulnerability to develop future episodes of depression. These results are in line with the suggestion that emotional changes resulting from ABM would only be visible after a period of time has passed or in response to a subsequent stressor (Wells & Beevers, 2010). Attentional training may work as a cognitive 'vaccine' to decrease the impact of stressors and prevent relapses. Therefore, it might be possible that the lack of significant transfer effects in depressive symptom reduction in previous ABM studies (Baert et al., 2010; Kruijt et al., 2013) would be, at least in part, due to limitations in assessment procedures. Future ABM procedures require the evaluation of transfer effects to other tasks (e.g., stress tests, interpretation bias tasks).

5.1.2.4. *Suitable control groups*

The selection or design of a suitable control group is a challenging issue in experimental psychopathology. Indeed, it is difficult to find a conceptually valid control group for CBM paradigms (Koster, Baert, Bockstaele, & De Raedt, 2010). For instance, in the typical modified dot-probe control condition, known also as sham control condition, the dot follows the neutral stimulus in half of the trials and follows the negative stimulus in the remaining trials. Hence, there is no contingency between stimulus valence and the dot probe. Although this procedure is routine in experimental psychology (Rescorla, 1967), the rationale for using it in ABM is debatable. In dot-probe based ABM procedures, the control group is not a pure control condition since participants are exposed to negative stimuli contingencies (as well as neutral stimuli contingencies) in half of the trials, which might alter patterns of processing and influence emotional responding (Blackwell, Would, & MacLeod, 2017).

5.2. Overcoming the limitations of ABM procedures

In recent years, researchers have tried to overcome these previous limitations using eye-tracking paradigms to modify attentional patterns. For instance, Price et al. (2015) used a one-session operant conditioning paradigm in a sample of healthy undergraduates to reward gazes towards happy faces or neutral faces. In this procedure, participants were presented with a set of six female faces (five emotional faces -happy, sad, angry, fearful, and disgusted- and a neutral one) during each trial. Although participants were not informed of the reward contingency, each trial ended when they fixated their gaze on the target stimulus (i.e., the experimental group on the positive face and the control group on the neutral face) for 250ms. The authors found that individuals trained to pay attention to happy faces reacted with less intensity in a stress-induction task involving negative feedback after a bogus intelligence test. The authors interpreted these results as suggesting that this novel procedure may buffer against stress reactions. In a similar study, Ferrari, Möbius, van Opdorp, Becker & Rinck (2016) devised an ABM procedure in which healthy participants had to focus on a fixation cross in one of four quadrants of a computer screen. After fixation, a set of 4 pictures (2 negative, 2 positive) appeared. In the positive training condition, participants had to maintain their attention on positive stimuli (i.e., trials where a positive picture replaced the previously fixated cross area), and to disengage their attention from negative stimuli (i.e., trials where a negative picture replaced the previously fixated cross area), engaging and maintaining attention on surrounding positive stimuli. This was achieved by implementing an eye-tracking procedure in which the trial did not continue until the system detected a sufficiently long fixation on one of the positive pictures displayed on the screen (i.e., 1000 ms) and then a target (i.e., an arrow pointing left or right) replaced the new fixated picture and participants had to indicate its direction. Similar to Price et al. (2015), the researchers did not tell participants about the contingency between gaze patterns and task performance. Compared to a negative training condition (where the eye-tracker was designed to detect visual fixations on negative pictures), the positive ABM induced longer fixations on positive pictures and faster attentional disengagement from negative pictures. However, such benefits did not transfer to diminished emotional reactions in response to a subsequent stressor.

Although these methods highlight the possibility of training attention via eye-tracking technologies, it should be noted that in both studies the control group was also trained to direct their attention away from emotional stimuli (i.e., neutral faces – Price et al., 2015) or to fixate the gaze on negative stimuli (i.e., negative pictures – Ferrari et al., 2016). Thus, there is a contingency between control-participants' attentional patterns and successful task performance. Therefore, the differences in attentional performance found between groups may be due to the absence of a "pure" control group with no contingencies between gaze patterns and task performance. Further, previous research has found that explicitly instructing participants to redirect attention from negative to positive information and providing them with online feedback on their performance can increase top-down regulation of attention and diminish emotional reactions to stressors

(Sanchez et al., 2016). However, participants in these previous studies (Price et al., 2015; Ferrari et al., 2016) did not received any explicit instruction regarding the role of their gaze on task performance.

Taking all the evidence together, the inclusion of individualized feedback on trainees' performance during attention training, the use of an adequate control group, and explicit guidance regarding the deployment of attention in the intended direction, may be a promising approach to ascertain the benefits of training attention using eye-tracker methodology in depression. Therefore, in the next chapter, we aimed to develop a novel eye-tracking ABM method for treating depression-related attentional biases, trying to overcome the previous limitations of current ABM procedures.

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CHAPTER 6: ATTENTIONAL BIAS TRAINING THROUGH AN EYE-TRACKER BASED PARADIGM: A PROOF OF PRINCIPLE STUDY.[1]

The proposal of a new ABM intervention: Background, objectives, and hypothesis.

Taking together all the conceptual and methodological considerations and limitations of current ABM procedures pointed out in the previous chapter, the main aim of this dissertation was to develop and apply a new eye-tracking paradigm to modify specific components of attentional biases in depression. The use of eye-tracking technology enables us to train attention by following strict performance and time-based criteria as well as to specify the components of attention (i.e., disengagement from negative information, engagement and maintenance on positive information) to be targeted in the training, providing a theory-driven intervention (Koster, Baert, Bockstaele, & De Raedt, 2010).

The proposed ABM procedure accomplishes this by providing individualized trial-by-trial feedback on trainees' gaze allocation during the attentional processing of different emotional stimuli. This new procedure should maximize awareness of attention allocation to increase regulatory control in redirecting attention in an adaptive manner (Sanchez, Everaert & Koster, 2016; Bernstein & Zvielli, 2014). In previous eye-tracking ABM paradigms (Ferrari, Möbius, van Opdorp, Becker, & Rinck, 2016), participants had to disengage their attention from negative information and maintain it on positive information in order to advance to the next trial. Therefore, there was contingency

[1] Part of the information described in this chapter corresponds to the published article:
Vazquez, C.*, **Blanco, I**.*, Sanchez, A., & McNally, R. J. (2016). Attentional bias modification in depression through gaze contingencies and regulatory control using a new eye-tracking intervention paradigm: study protocol for a placebo-controlled trial. BMC Psychiatry, 16(1), 439. doi:10.1186/s12888-016-1150-9.

between attentional patterns and correct task performance. However, different from Ferrari et al., (2016) method, in the current study, we aimed to develop a novel ABM method for treating depression-related attentional biases, relying not only on the use of eye-tracking contingencies, but also on online feedback and explicit implementation of top-down regulation to train attentional patterns (Sanchez, Everaert & Koster, 2016).

Furthermore, a significant improvement of our proposed experimental design over previous studies is related to the control group. In the typical control group of dot-probe ABM, the dot replace both stimuli (e.g., negative and neutral words) the same percentage of times. Therefore, there are contingencies between the gaze and the negative stimuli (and the neutral one). Further, in other studies, the opposite attentional pattern (e.g, disengaging from positive stimuli and engaging on negative stimuli) to the training target are trained – (See Ferrari et al., (2016). In our study we have designed a 'yoked-control' condition where participants in the control group were exposed to the same experimental stimuli the same amount of time as participants in the experimental condition, but without receiving any type of training or contingency for those stimuli. The purpose of this design was to compare the effects of our attentional training (i.e., disengage from negative information and maintain gaze on positive information) with the natural attentional patterns of the control group when they are exposed to the same stimuli, the same amount of time, but without receiving any contingency, feedback or instruction. Thus, we assure that lack of contingency is the critical difference between the experimental and the control group, which minimizes the problem of finding an adequate control group in ABM paradigms (Blackwell, Would, & MacLeod, 2017).

Additionally, we also aim to test whether training effects transfer to measures of emotional responding under non-stressful and stressful conditions and whether beneficial effects are evident in other measures relevant to emotional regulation (e.g., rumination, interpretation biases, satisfaction with life, etc.). Finally, the last improvement of the current study over prior studies was the use of the emotional faces validated in Chapter 3 of this dissertation as the stimuli to assess attentional biases controlling for the influence of teeth visibility (Calvo & Nummenmaa, 2008; 2011) and low-level features of the pictures (i.e., luminance) – (Raila, Scholl & Gruber, 2015) on attentional patterns.

In contrast to other recent innovative approaches that have used eye-tracking paradigms to modify the attentional patterns of healthy samples (Sanchez, Everaert & Koster, 2016; Price, Greven, Siegle, Koster, & De Raedt, 2015, Ferrari et al., 2016), our study counts as a proof of principle study illustrating how researchers can use eye-tracking methods to try to modify gaze patterns in people with subclinical depression.

We first hypothesized that, after the attentional training, trained participants, compared to yoked-control participants, would spend significantly more time looking towards happy faces regardless of whether these faces were accompanied by sad or neutral faces. Also, we hypothesized that, after the training, trained participants would spend significantly less time looking at sad faces, regardless of whether these faces were accompanied by happy or neutral faces.

Second, we also hypothesized that changes in attentional biases would show transfer effects to related variables such as depressive symptoms, rumination, or affect. Thus, we expected that participants in the trained group, compared to those in the yoked-control group, would show a significant increase in their positive affect and a significant decrease in their depressive symptoms, rumination and negative affect after the attentional training.

Finally, previous research has proposed that attentional biases to emotional information are related to subsequent biased processing of this information (i.e., interpretation biases of emotional information) - (Everaert, Koster, & Deraksha, 2012; Joormann & Vanderlin, 2014; Sanchez, Duque, Romero & Vazquez, 2017). Therefore, we hypothesized that experimental participants would show a significant decrease in their negative interpretation bias compared to yoked-control group participants. Further, following previous studies (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002), we also expected that the attentional training would enhance stress tolerance. Thus, we hypothesized that if both groups were exposed to a stress task, the experimental participants would show less negative reactions (i.e., less negative affect and more positive affect) than their counterparts in the yoked-control group.

Method

Study design overview

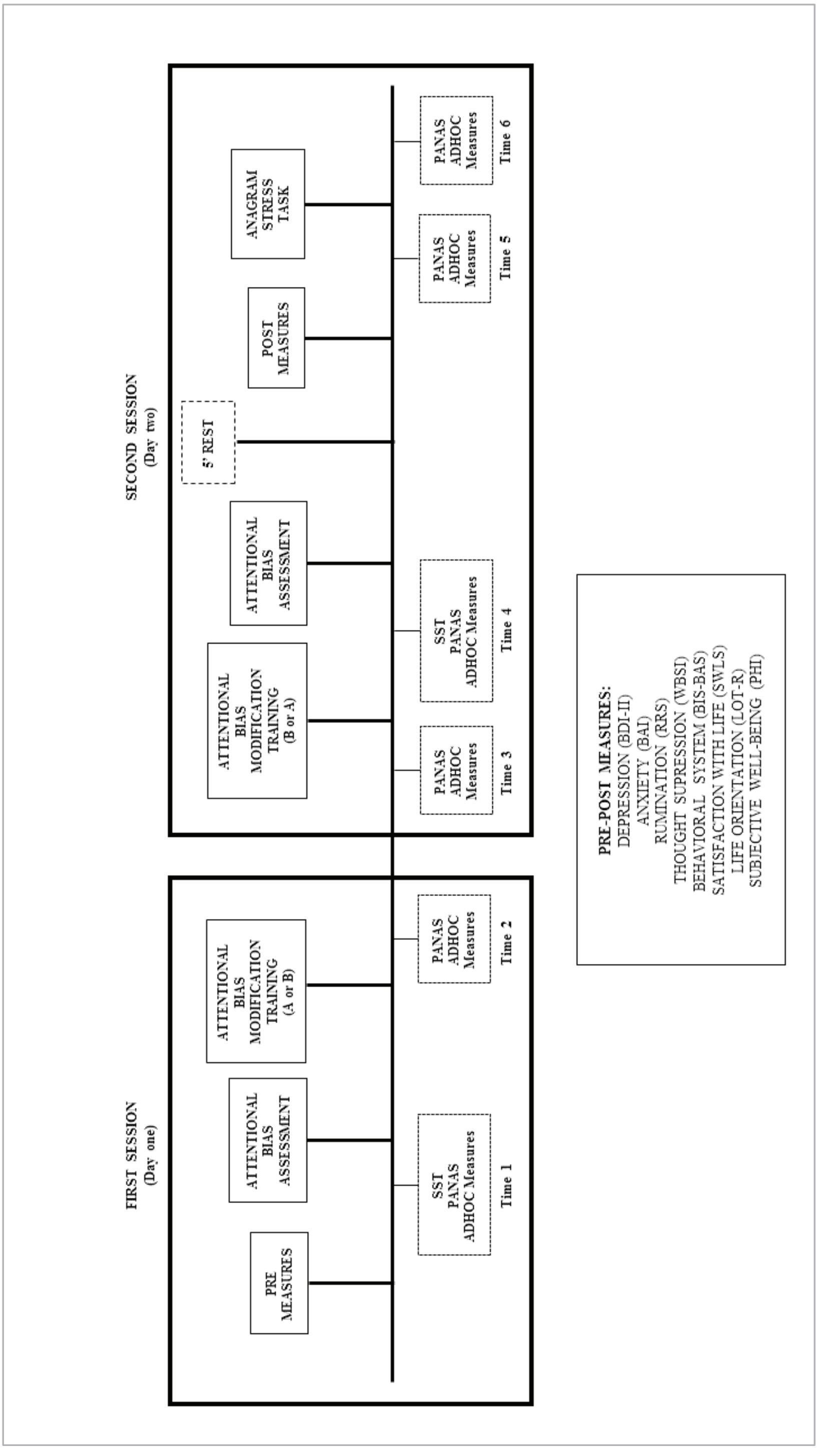
The study involved a repeated-measures design across two assessment times (pre-attentional training and post-attentional training). The pre-post assessment included questionnaires evaluating depression and anxiety symptoms as well as psychological vulnerability factors for depression (i.e., rumination, thought suppression, and approach and avoidance behaviour) and protective factors against depression (i.e., satisfaction with life, optimism and well-being).

The pre-post assessment also included the evaluation of direct effects of the training on attentional performance by using a visual attention task, Attentional Bias Assessment (ABA), different from the one employed in the Attentional Bias Modification Training (ABM-T), which can be considered as an improvement over previous studies (Wells &

Beevers, 2010; Tsumura, Shimada, Nomura, Sugaya, & Suzuki, 2012) Furthermore, the pre-post assessment involved measures to evaluate transfer effects of the ABM-T to other related relevant cognitive processes in depression such as interpretation of ambiguous information (a Scrambled sentences task, SST) - (Wenzlaff & Bates, 1998).

The entire experiment was conducted over two consecutive days in the laboratory. The ABM-T was administered during the two sessions, immediately after the pre-assessment (session 1) and immediately before the post-assessment (session 2). In session 2, immediately following the ABM-T and the post-assessment, a stress task was conducted to evaluate the transfer of the ABM-T on stress reactions. Additionally, immediately before and after each ABM-T application, current positive and negative affect were evaluated. Further, current boredom, fatigue, curiosity and entertainment were also assessed. Thus, these variables were assessed six times across the entire experiment (Time 1: before first ABM-T application, Time 2: after first ABM-T application, Time 3: before second ABM-T application, Time 4: after second ABM-T application, Time 5: Before stress task, and Time 6: After stress task). At the end of the study, participants were debriefed by the experimenter. Each of the two sessions lasted approximately 80 minutes. (See Figure 6.1).

Figure 6.1. Repeated-measures study procedure

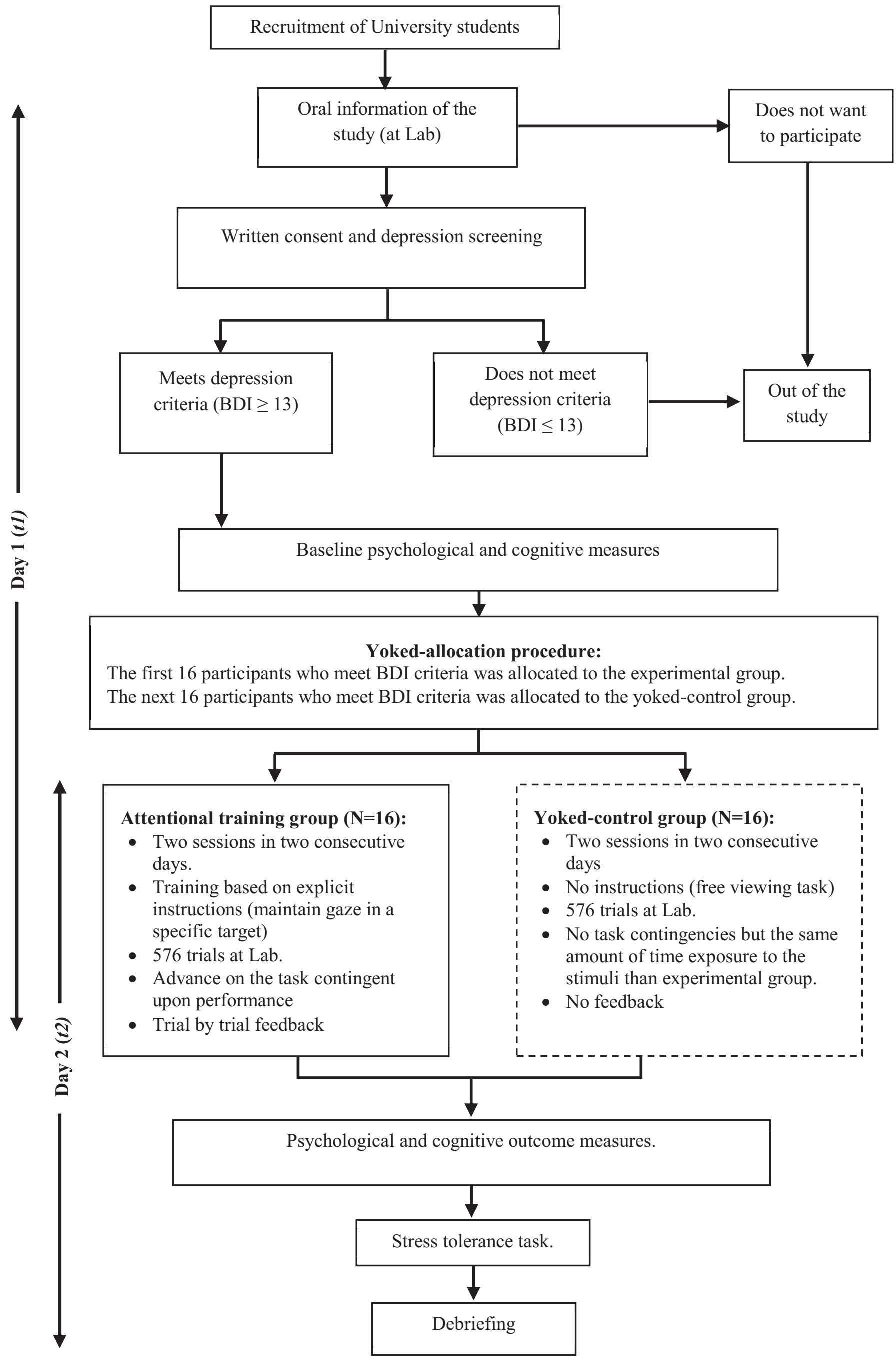


Participant recruitment and allocation

The sample size of the present study was determined according to power calculations (G*Power; Erdfelder, Faul, & Bucjner, 2009) and based on Cristea, Kok and Cuijpers (2015) meta-analysis effect size (g = .33) with α = .05, and 1-β = .95. A total of 32 dysphoric university students (91% female; 9% male) with a mean age of 20.38 years (SD = 2), ranged from 18 to 26 years, voluntarily took part in the study. Participants were selected based on their scores on Beck Depression Inventory-II - BDI-II (Beck, Steer, & Brown, 1996). As in the previous study (Chapter 4), a 13 points cut-off score was used (Dozois, Dobson, & Ahnberg, 1998). All participants had normal or corrected-to-normal vision via contact lenses or glasses if required. Those participants who complete the two-session of the study received course extra-points anda book as a reward for their participation.

As the study is a registered clinical trial (ClinicalTrials.gov NCT02847793) with a yoked-control condition, participants were allocated to the experimental and the control group once they arived to the lab. First, the all the first 16 consecutive participants were assigned to the experimental group until it was completed. Then, once the mean exposure times were analyzed for this group, the next 16 consecutive particiapnts were allotted to the yoked-control group. Thus, the control group was 'yoked' to the experimental on the basis of equaling the average total time exposed to the experimental stimuli (see Figure 6.2).

Figure 6.2. Study flow diagram



Psychological Measures

The BDI-II (Beck, Steer, & Brown, 1996) was used to evaluate depressive symptoms of the sample. BDI-II is a 21-item self-report inventory. Each item has four statements ranging from a 0 to 3 scale. The internal consistency of our sample was acceptable (α = .74).

The Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1998) was applied to evaluate anxiety symptoms. It is composed by 21 self-report items that indicate the severity of anxiety symptoms on a 0 ("not at all") to 4 ("Severely") Likert scale. The reliability of this inventory in the present study (α = .82).

Ruminative Responses Scale (RRS; Nolen-Hoeksema & Morrow, 1991) is a 22 self-report items scale that was used to assess participants' rumination cognitive style by a four points Likert scale ranging from 1 ("almost never") to 4 ("almost always"). It has two subscales that evaluate the brooding and reflection components of rumination. The reliability of the scale in our sample was acceptable (α = .72).

The White Bear Suppression Inventory (WBSI; Wegner & Zanakos, 1994) was used to evaluate thought suppression. It is a 15-item self-report inventory with a Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree") on which participants indicate their agreement with each statement. The inventory has shown an acceptable reliability in the present sample (α = .74).

The Behavioral Inhibition System and Behavioral Approach System Scale (BIS/BAS, Carver & White, 1994) was used to evaluate general motivational systems that underlie human behaviour. It is composed by 24 self-report items with a 4 point Likert scale ranging from 1 ("very true for me") to 4 ("very false to me"). The BAS component is composed by three subscales: Drive, Fun seeking and reward responsiveness. BIS/BAS reliability in our sample was low (α = 67).

Satisfaction with Life Scale (SWLS, Diener, Emmons, Larsen, & Griffin, 1985) was used to evaluate participants' life satisfaction. It is a short 5-item self-report Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). The reliability of SWLS in our sample was good (α = .83).

Life Orientation Test Revised (LOT-R, Scheier, Carver & Bridges, 1994) was used to assess optimism and pessimism as a dispositional variable. The LOT-R is a ten-item self-report Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). The reliability of LOT-R in the present study was good (α = .81)

The Pemberton Happiness Index (PHI, Hervás & Vázquez, 2013) is an 11-item self-report scale of hedonic, eudaimonic, and social well-being (ranging from 0 – strongly disagree – to 10 – strongly agree) and was applied to evaluate participants' well-being. Its reliability in the present study was very good (α = .90).

The Positive and Negative Affect Schedule (PANAS, Watson, Clark y Tellegen, 1988) is a 20-item self-report schedule that assess the presence of positive and negative affect throughout a scale ranging from "not at all" to "very much". PANAS reliability in the present sample was good for both Positive Affect factor (α = .85) and for the Negative Affect one (α = .84).

Four *ad hoc* items were created to assess participants' boredom, fatigue, curiosity and entertainment across the study. These adjectives reflect a dimension of Deactivation/Arousal (e.g., Russell, 1980), that can be relevant as a measure of other type of reactions that an ABM task may induce. In a 10-point Likert-scale (ranging from 0 - nothing at all to 10 – very much) participants rated their current boredom (*"I feel bored"*), fatigue (*"I feel tired"*), curiosity (*"I am curious"*) and entertainment (*"*I am entertained"). Curiosity and entertainment items were inverted, and a total sum score of Deactivation/Arousal was calculated for the subsequent analysis. Therefore, high total scores reflected high levels of deactivation whereas low total scores reflected low levels of deactivation.

Eye-tracker device

As in the previous studies (Chapter 3 and 4), the location and movements of the participants' eyes were recorded and measured with a Tobii tx-120 infrared eye-tracker system with a 120 Hz frequency (approximately, coordinates were recorded every 8.35ms). The distance between the eye tracker and the participants' eyes was 60 cm, controlled by an anatomic chair maintaining the participants' head in a comfortable, but stable, position. Moreover, a five-point calibration was done before starting each attentional task. These procedures occurred in a sound-proof room.

Attentional Tasks' Stimuli

The Karolinska Directed Emotional Faces database - KDEF (Lundqvist, Flykt, & Öhman, 1998) was used on the Attentional Bias Assessment Task (ABA). A total of 18 pictures (half men, half women) were selected from the A series of KDEF displaying two different emotions (i.e., happy and sad). Thus, our procedure, which is similar to that used in the previous study, included 36 emotional faces (18 happy, 18 sad) and its corresponding neutral paired face (18 neutral faces).

For the Attentional Bias Modification Training (ABM-T), and in order to avoid possible interference or habituation to the ABA emotional faces, we used 12 models (half men, half women) from a different face database. ABM-T pictures were selected from the FACES database created at the Max Planck Institute for Human Development (MPIB - Ebner, Riediger, & Lindenberger, 2010). As in the ABM-T task, only two types of emotions were used (12 happy and 12 sad) plus a set of 12 neutral expressions of the same actors/actress.

All the faces used in both the ABA and the ABM-T task were presented in a frontal view. As teeth visibility artificially attracts viewer's attention (Savage, Lipp. Craig, Becker, & Horstmann, 2013; Blanco, Serrano-Pedraza, & Vazquez, 2017), they were covered by a grey Gaussian-type filter which optimizes gaze patterns towards more informative emotional areas of the face (Blanco, Serrano-Pedraza, & Vazquez, 2017). All pictures were cropped and edited using Adobe Photoshop CS3. First, faces were converted to a grey scale and all non-emotional features, such as surrounding parts, were cropped (Sanchez & Vazquez, 2013). All pictures were then introduced into a grey square background (512 x 512 pixels). To blur the crop procedure, the outline of the faces was shade into the background. The teeth of the happy pictures were blurred by using a 10-pixel Gaussian filter. To avoid differences on energy or luminance, the contrast energy of all the pictures was equated for both the assessment and training tasks (Blanco, Serrano-Pedraza, & Vazquez, 2017, Aguado, García-Gutierrez, & Serrano-Pedraza, 2009). Furthermore, a gamma correction was applied to the 24'' BENQ LCD monitor where the stimuli were displayed. The presentations of the stimuli on the ABA task was controlled through Tobii Studio software (2.0.6), whereas the stimuli presented during ABM-T task were controlled with an integration of Tobii Studio software (2.0.6) and E-Prime Studio software (2.0.8.22).

Attentional Bias Assessment Task (ABA).

The same attentional paradigm as in chapter 4 was used to assess participants' attentional bias. Each trial began with a grey screen for 500 ms followed by a white cross fixation displayed at the centre of the grey screen. Immediately thereafter, a random white number (1 to 3 and 7 to 9) replaced the cross for 1000ms. To ensure that participants maintain their attention on the centre of the screen, we asked participants to read the number out loud as quickly as possible (Calvo & Avero, 2005). Afterwards, a pair of emotional faces (happy vs. sad; happy vs. neutral; sad vs. neutral) was displayed for 3500ms. Participants were instructed to freely look at the faces, without any constraints, until the beginning of the next trial. Each emotional face was presented equally often, and its position on the screen (right or left side) was counterbalanced. In total, the task was composed of 36 happy vs. sad, 36 happy vs. neutral and 36 sad vs. neutral trials that appeared in random order. The entire task lasted about 12 min.

Attentional Bias Modification Training Task (ABM-T).

A wait-for-fixation paradigm was used in the experimental group to train participants' attentional patterns. In this paradigm, the progress of each trial depends on the maintenance of participants' gaze to a previously determined target stimulus during a pre-specified length of time. In our paradigm, experimental participants were instructed to maintain their gaze on the most positive face of the pair (e.g., in the neutral vs. sad trials, participants had to hold their gaze at the neutral face; in the neutral vs. happy trials participants had to hold their gaze at the happy face). Furthermore, to increase participants' motivation in the task, especially challenging for depressed people (Koster & Hoorelbeke, 2015), the cognitive demand of the task increased across trials. Whereas in the first set of trials, participants had to hold their gaze on the target stimulus for 750ms, in the second set they had to do so for 1,500ms to advance to the next trial. Within each block, participants first performed the low demand condition (750ms) before doing the high demand one (1500ms).

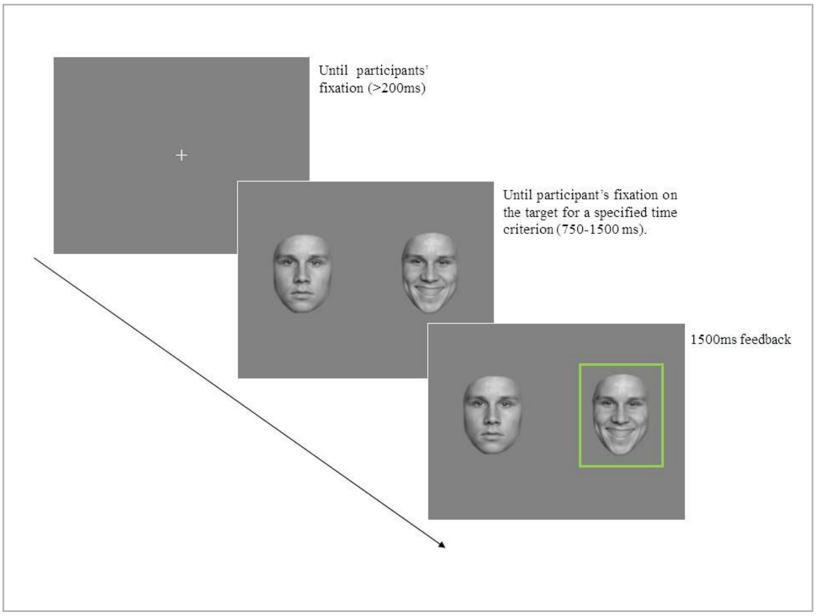
The task was composed of three independent blocks (happy vs. neutral; sad vs. neutral; and happy vs. sad). Each block, consisting of 96 trials, was administered twice (i.e., one in each of the two training sessions). Both sessions finished with the happy vs. sad block, as the others blocks were counterbalanced across subjects. Thus, the entire task consisted of two independent sessions (two consecutive days) with 288 trials each (576 trials in total). Faces appeared equally often, and their position on the screen was counterbalanced. Also, to reduce habituation and to foster adherence, we randomly distributed the position of the faces along the horizontal or vertical axis of the screen.

In every block and condition, each trial began with a grey screen for 500ms, followed by a white fixation cross appearing at the center of the screen until the participants fixated their gaze for 200ms on it (Sanchez, Everaert, De Putter, Mueller, & Koster, 2015; Sanchez, Everaert, & Koster, 2016). After this initial required fixation, two faces were simultaneously displayed on the screen until the required fixation on the target (i.e., 750ms or 1,500ms) was detected by the eye-tracker. As an immediate consequence of this fixation, a green square was displayed on the face where the fixation had taken place (e.g., a neutral face in a neutral-sad trial; a happy face in a neutral-happy trial) providing immediate feedback to the participant (See Figure 6.3). Each training session lasted approximately 30 minutes.

Control group in the Attentional Bias Modification Training Task (yoked-control group)

For participants in the experimental group, the wait-for-fixation ABM-T paradigm implied that each trial ends once the participant has spent a given amount of time looking at an area of interest (e.g., a happy face). Thus, in the experimental group, the duration of each trial was contingent upon the time each participant devoted to the target stimulus. An ideal control condition would be one in which participants in that condition would be exposed to the same amount of stimuli and the same total time of exposure.

Figure 6.3. Attentional Bias Modification Training Task. Example of a happy-neutral condition trial.



To achieve this goal, we used a yoked control group (Seligman & Maier, 1967). Participants in the experimental group were the first ones to participate in the study, and we measured the average total time they spent on each trial. Control participants were exposed ("yoked") to the same amount of time as participants in the experimental group, but they did not receive any type of explicit instruction or feedback. In carrying out this novel procedure in the context of ABM, we ensured that participants in the experimental and control groups differed only in two ways: the experimental group had an explicit instruction and also experienced a contingency between their gaze behaviour and feedback, whereas the control group did not.

Scrambled Sentence Task (SST).

SST is an experimental task designed to evaluate interpretation biases (Wenzlaff & Bates, 1998). It consists of 20 scrambled sentences of 6-words each. Participants' task is to unscramble the sentences by using only 5 words. Each sentence can be unscrambled in a positive or negative manner (e.g., equal am others I inferior to). Further, cognitive load (i.e., remember a 6-digit number) was used to deplete working memory resources and enable the appearance of negative schemas. Participants were instructed to unscramble as many sentences as possible in 2.5 minutes. A measure of interpretation bias derived by computing the proportion of negatively unscrambled sentence divided by the total of unscrambled sentences (Wenzlaff & Bates, 1998).

Anagram Stress Task (AST)

To assess stress tolerance and changes in emotional vulnerability after the attentional training, an adaptation of the anagram stress task procedure (MacLeod et al., 2002) was administered. To design the anagram stress task (AST), 66 anagrams were selected from the Internet. An independent sample of 101 undergraduate students completed and rated the difficulty of the anagrams categorizing them as "very easy, easy, normal, difficult, very difficult". Twenty solvable but difficult (or very difficult) anagrams were selected. These anagrams were rated as difficult (or very difficult) by 83%

of the sample. Another 20 anagrams were selected from the Internet and one or two letters from them were deleted to create unsolvable anagrams. Therefore, the final AST comprised 40 anagrams (20 difficult -or very difficult- but solvable anagrams, and 20 irresoluble anagrams).

In the AST, participants were informed that their cognitive performance was assessed by the ability to solve anagrams and they were instructed to solve as many anagrams as possible in a 3-minute period. Each anagram appeared on the screen one at a time. At the end of the task, a false feedback slide (*"Your performance has been much worse than the average"*) was displayed, and participants' mood was assessed. At the end of the experiment participants were fully debriefed by the experimenter about the purpose of the procedure.

Results

Data filtering and attentional measures

As done in Chapter 4, to filter the attentional bias data we followed Raila, Gruber, & Scholl's (2015) guideline. Also, the same dependent variables were used (i.e., latency to first fixation, duration of the first fixation, and total fixation time on each emotional face). Attentional biases indices were calculated based on these dependent variables (see Chapter 4).

Demographics and group characteristics

As shown in Table 6.1, there were no significant differences in age or sex between the experimental and the yoked-control group. Further, following Dozois, Dobson, &

Ahnberg (1998) cut-off scores, the mean depressive scores of both groups fitted in the mild-depression range. (see Table 6.1)

Table 6.1. Group differences at baseline scores

	Experimental (N = 16)	Yoked-control (N = 16)	
	M *(SD)*	M *(SD)*	Statistic *(p)*
Age	20.25 *(1.6)*	20.5 (*2.4*)	t = .35 (*p* = .73)
Female (%)	100	81.25	X^2 = 3.31 (*p* = .07)
Depressive symptoms (BDI-II)	18.56 (*7.32*)	19.12 (*5.64*)	t = .243 (*p* =.81)
Anxiety symptoms (BAI)	14.62 (*8.31*)	15.56 (*6.22*)	t = .361 (*p* =.72)
Rumination (RRS)	21.19 (*5.18*)	21.5 (*5*)	t = .174 (*p* = .86)
Brooding	10.37 (3.2)	11.19 (3.19)	t = .719 (*p* =.48)
Reflection	10.81 (2.71)	10.31 (3.2)	t = -.477 (*p* =.64)
Thought suppression (WBSI)	35.5 (5.91)	33.93 (5.26)	t = -.790 (*p* =.44)
Behavioral approach system (BAS)			
Fun Seeking	11.94 (2.11)	10.75 (2.04)	t = -1.614 (*p* =.12)
Drive	9.31 (3.11)	10.25 (1.81)	t = 1.042 (*p* =.31)
Reward responsiveness	16.93 (1.39)	14.56 (2)	t = -3.903 **(*p* <.001)**
Behavioral inhibition system (BIS)	22.87 (2.25)	22.5 (3.65)	t = -.35 (*p* = .73)
Pessimism (LOT-R)	9.37 (2.1)	9.37 (2.28)	t = .000 (*p* =1)
Optimism (LOT-R)	9.1 (3.34)	7.25 (1.91)	t = -1.885 (*p* =.07)
General well-being (PHI)	6.17 (1.56)	5.47 (1.65)	t = -1.228 (*p* =.23)
Satisfaction with life (SWLS)	18.31 (5.86)	17.69 (6.51)	t = -.285 (*p* =.78)
Positive Affect (PANAS)	29.2 (6.5)	24.12 (5.1)	t = -2.453 **(*p* =.02)**
Negative Affect (PANAS)	16.25 (4.57)	13.81 (4.1)	t = -1.591 (*p* =.13)
Deactivation/Arousal	10.90 (5.35)	13.62 (3.5)	t = 1.720 (*p* = .096)

Notes. M = Mean; *SD* = Standard Deviation. Significant differences are marked in bold letters.

Differences between groups on psychological measures at baseline scores.

A series of independent samples T-tests were carried out in order to evaluate differences in baseline psychological measures between groups. As shown in Table 6.1, groups did not differ in depression and anxiety symptoms, rumination (brooding and reflection), thought suppression, behavioural activation system (Fun seeking and drive), behavioural inhibition system, pessimism, optimism, general well-being, satisfaction with life and negative affect state. However, participants in the experimental group had more positive affect state and higher levels of reward responsiveness than their counterparts in the yoked-control group.

Changes in attentional indexes after the ABM-T

A series of 2 (Group: experimental, yoked-control) x 2 (Time: pre-attentional training, post-attentional training) x 3 (type of trial: Happy vs. Neutral; Sad vs. Neutral; Happy vs. Sad) mixed ANCOVAs (controlling for positive affect and reward responsiveness) were carried out to evaluate the effects of ABM-T on attentional biases. Each ANCOVA was independently carried out for each attentional index separately.

- *First fixation latency.* Results showed no significant main effects (group F (1, 28) = .107, p =.746; time F (1, 28) = .623, p =.437, or type of trial F (2, 56) = 1.945, p = .153). Further, no significant two-way or three-way interactions (group x time F (1, 28) = 1.117, p = .300; group x type of trial F (2, 56) = .603, p = .550; time x type of trial F (2, 56) = .763, p = .471; and group x time x type of trial F (2, 56) = .169, p = .845) were found.
- *First fixation duration*. Similarly, there were no significant main effects (group F (1, 28) = 2.799, p =.105; time F (1, 28) = .181, p =.674, or type of trial F (2, 56) = .669, p = .516). Further, no significant two-way or three-way interactions (group x time F (1, 28) = .302, p = .587; group x type of trial F (2, 56) = 2.312, p = .108; time x type of trial F (2, 56) = 1.085, p = .345; and group x time x type of trial; F (2, 56) = 2.004, p = .144) were found.

- *Total fixation duration*. Again, there were no significant main effects (group F (1, 28) = .340, p =.564; time F (1, 28) = 1.004, p =.325, or type of trial F (2, 56) = .608, p = .548). Further, no significant two-way or three-way interactions (group x time F (1, 28) = .082, p = .777; group x type of trial F (2, 56) = 1.121, p = .333; time x type of trial F (2, 56) = .624, p = .540; group x time x type of trial F (2, 56) = .015, p = .985) were found.

Changes in psychological measures after the ABM-T.

A series of 2 (Group: Experimental, yoked-control) x 2 (Time: pre-attentional training, post-attentional training) mixed ANOVAs were carried out to evaluate differences in psychological measures between groups after the training.

- *Depressive symptoms.* Results showed no significant two-way interaction (group x time F (1, 30) = .023, p = .881). Further, no significant group or time main effects emerged in our analysis (both p > .142).
- *Anxiety symptoms.* Results showed no significant group or time main effects in our analysis (both p > .221). Further, no significant two-way interaction (group x time F (1, 30) = .001, p = .975) emerged in our analysis.
- *Thought suppression.* Results showed no significant main effects of group or time (both p > .332). However, a significant group x time interaction emerged in our analysis (F (1, 30) = 4.329, p = .046, η^2 = .126). Bonferroni post-hoc test revealed that in the post-attentional training assessment, the yoked-control group showed a significant increase in its levels of thought suppression compared to the initial levels measured in the pre-attentional training assessment (p < .038) whereas there were no significant differences between groups on either the pre- or post-attentional training assessment (both p > .436).

Table 6.2. Mean attentional scores of the trained and yoked-control groups to each pair of faces before and after training.

	Happy-Neutral trials				Sad-Neutral trials				Happy-Sad trials			
	Happy face		Neutral face		Sad face		Neutral face		Happy face		Sad face	
	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training	Pre-training	Post-training
First Fixation Latency (ms)												
Trained group	639	522	669	685	657	645	681	642	562	555	675	726
Yoked-control group	504	617	619	657	549	632	602	661	541	642	601	614
First Fixation Duration (ms)												
Trained group	418	587	334	431	356	468	353	500	418	552	373	487
Yoked-control group	382	423	388	452	394	443	376	436	378	429	398	448
Total fixation duration (ms)												
Trained group	1573	1727	1195	1121	1333	1314	1434	1509	1524	1716	1244	1104
Yoked-control group	1555	1565	1516	1488	1607	1572	1454	1474	1457	1500	1606	1524

- *Rumination.* Again, no significant main effects of group or time emerged in our analysis (both p > .438). However, a marginally significant group x time interaction emerged (F (1, 30) = 3.762, p = .062, η^2 = .111). Bonferroni post-hoc test revealed that after the ABM-T the experimental group showed a marginally significant increase of their levels of rumination compared to their levels before the ABM-T (p < .063). However, there were no differences between groups on either the pre- or post-attentional training assessment (both p > .240). Regarding the brooding component of rumination, our analysis did not reveal group or time main effects (all p > .311) or significant group x time interaction (F (1, 30) = 3.324, p = .078). Similarly, with regard to the reflection component our results showed no significant group and time main effects (both p > .356) or group x time interaction (F (1, 30) = 3.062, p = .247).
- *Behavioral activation system*. Regarding the first component of the measure, Fun seeking, our results showed no significant group or time main effects (both p > .131) or group x time interaction (F (1, 30) = .068, p = .796). Regarding the second component of the measure, Drive, our results also showed no significant group and time main effects (both p > .250) or group x time interaction (F (1, 30) = .2.871, p = .101). Finally, with regard to the reward responsiveness component, our results also showed no significant main effect of time (p > .888) or group x time interaction (F (1, 30) = .507, p = .482). However, a significant group main effect emerged in our analysis (F (1, 30) = 13.56, p = .001, η^2 = .311). Bonferroni post-hoc comparisons showed that the experimental group had higher levels of reward responsiveness than their counterparts in the yoked-control group (p = .001).

- *Behavioral inhibition system.* Results showed no significant group or time main effects (both $p = 1$). Further, no significant two-way interaction (group x time F (1, 30) = 1.656, $p = .208$) emerged in our analysis.
- *Pessimism.* Results showed no significant group or time main effects (both $p >$ .284) and no significant two-way interaction (group x time F (1, 30) = 1.189, $p =$ .284).
- *Optimism.* Results showed no significant main effects of time ($p = .185$) and no significant two-way interaction (group x time F (1, 30) = 0, $p = 1$). However, a marginally significant main effect of group emerged, F (1, 30) = 4.034, $p = .054$; $\eta^2 = .119$). Bonferroni post-hoc comparisons revealed that the experimental group reported higher levels of optimism than the yoked-control group ($p = .054$).
- *General well-being.* Results showed no significant group or time main effects (both $p > .177$) and no significant two-way interaction (group x time (F (1, 30) = .328, $p = .572$).
- *Satisfaction with life.* Results showed no significant group or time main effects (both $p > .188$). Further, no significant two-way interaction (group x time (F (1, 30) = 1.451, $p = .238$) emerged in our analysis.

Changes in positive and negative affect across the entire study.

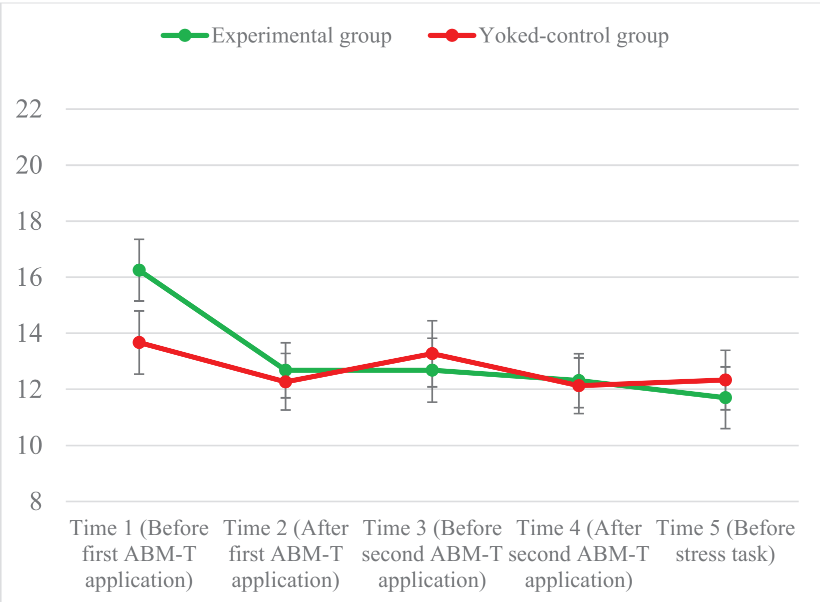
A series of 2 (Group: Experimental, Control) x 5 (Time: Time 1: before first ABM-T application, Time 2: after first ABM-T application, Time 3: before second ABM-T application, Time 4: after second ABM-T application, Time 5: Before the stress task) mixed ANOVAs were carried out to assess changes in positive and negative mood across the entire experiment. Each ANOVA was conducted separatedly for positive and negative affect.

- *Positive Affect*. Results showed a significant main effect of group (F (1, 29) = 5.996, p = .021, η^2 = .171), and time (F (4,116) = 11.90, p < .001, η^2 = .291). These main effects were qualified by a significant group x time interaction (F (4, 116) = 3.182, p = .016, η^2 = .099). Bonferroni post-hoc comparisons showed significant differences between both groups on Time 1, Time 4 and a marginal significant effect on Time 5. Specifically, the experimental group showed higher positive affect than the yoked-control group at Time 1 and Time 4 (both p < .021) and also at Time 5 (both p < .062). Additionally, Bonferroni post-hoc test also revealed a significant decrease in positive affect from Time 1 to Time 2 both in the yoked-control (p = .006) and the experimental group (p < .001). However, a significant increase in positive mood from Time 2 to Time 3, Time 4 and Time 5 was found in the experimental group (all p < .003). See Figure 6.4

Figure 6.4. Changes in positive affect across the entire experiment.

- *Negative Affect*. Results showed a non-significant main effect of group (F (1, 29) = .097, p = .758) or significant group x time interaction (F (4, 116) = 1.962, p = .105). However, analysis revealed a significant main effect of time (F (4, 116) = 6.475, $p < .001$, $\eta^2 = .183$). Bonferroni post-hoc comparisons showed a significant decrease of negative affect from Time 1 to Time 2, Time 4 and Time 5 (all p < .014) regardless of the group. See Figure 6.5

Figure 6.5. Changes on negative affect across the experiment

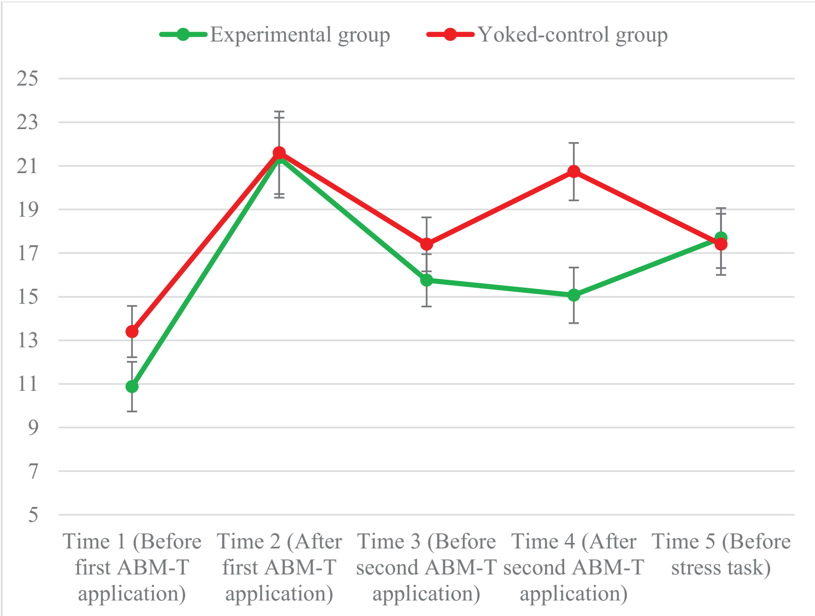


Changes in Deactivation/Arousal across the entire study.

A series of 2 (Group: Experimental, Control) x 5 (Time: Time 1: before first ABM-T application, Time 2: after first ABM-T application, Time 3: before second ABM-T application, Time 4: after second ABM-T application, Time 5: Before the stress task) mixed ANOVAs were carried out to assess changes in deactivation/arousal throughout the entire experiment.

Our results showed a non-significant main effect of group (F (1, 29) = 1.761, p = .195). However, a significant main effect of time (F (4,116) = 20.238, p < .001, η^2 = .411) and a significant group x time interaction (F (4,116) = 2.502, p = .046, η^2 = .079) emerged in our analysis. Bonferroni post-hoc comparisons showed a significant difference between both groups on Time 4 (p =.004). Specifically, participants in the yoked-control group reported higher levels of deactivation (i.e., higher levels of boredom and fatigue; and lower levels of curiosity and entertainment) than experimental participants. No other differences between groups were found (all p > .134). Additionally, Bonferroni post-hoc test also revealed a significant increase of deactivation from Time 1 to Time 2 both in the yoked-control (p < .001) and the experimental group (p < .001). Further, regarding the yoked-control group, Bonferroni comparisons showed a significant increase of deactivation from Time 1 to Time 2, Time 4 and Time 5 (all p < .015) and a marginally significant decrease of deactivation from Time 2 to Time 5 (p = .057). With regard to the experimental group, Bonferroni comparisons showed a significant increase of deactivation from Time 1 to Time 3, Time 4 and Time 5 (all p < .027); and a significant decrease of deactivation from Time 2 and Time 4 (p = .014). See Figure 6.5.

Figure 6.6. Changes in deactivation across the experiment



Changes in interpretation biases after the ABM-T.

A 2 (Group: Experimental, Control) x 2 (Time: pre-attentional training, post-attentional training) mixed ANOVA was carried out to assess changes in interpretation bias after the attentional training (i.e., changes in the proportion of negatively unscrambled sentence divided by the total of unscrambled sentences). Our results showed a non-significant main effect of group (F (1, 30) = 3.289, p = .080) or significant group x time interaction (F (1, 30) = .134, p = .717). However, analysis revealed a significant main effect of time (F (1, 30) = 6.878, p = .014, η^2 = .187). Bonferroni post-hoc comparisons showed that, regardless of the group, there was a significant decrease of the negative interpretation bias at Time 2 (p = .014).

Reaction to stress test after the ABM-T.

A series of 2 (Group: Experimental, Control) x 2 (Time: before stress task, after stress task) mixed ANOVAs was carried out to assess the emotional reaction after the stress task. These ANOVAs were carried out for both positive and negative affect separately.

- *Positive affect.* Results showed no significant two-way interaction (group x time F (1, 30) = .004, p = 950). However, a significant main effect of group (F (1, 30) = 7.912, p = .009, η^2 = .209) and time (F (1, 30) = 9.312, p = .005, η^2 = .237) emerged. Bonferroni post-hoc comparisons revealed that, in general, the experimental group showed higher levels of positive affect than the yoked-control group (p = .009). Further, both groups showed a significant reduction of positive affect after the stress task (p = .005).
- *Negative affect.* Results showed no significant two-way interaction (group x time F (1, 30) = .302, p = 587) and non-significant main effect of group (F (1, 30) = .000, p = .987). However, a significant main effect of time (F (1, 30) = 25.505, p < .001, η^2 = .460) emerged. Bonferroni post-hoc comparisons revealed a significant increase of negative affect, regardless of the group, after the stress task (p < .001).

Discussion

The aim of the present study was to develop and apply a new ABM training to overcome the limitations of previous ABM designs while developing a new strategy, based in training ocular movements, to modify attentional patterns in participants with high levels of depressive symptoms. Therefore, the influence of the ABM training on attentional performance and related psychological measures was analyzed. Further, the influence of the ABM training on the response to a subsequent stress task was also evaluated.

Our first hypothesis was that, after the attentional training, those participants in the experimental group, compared to those in the yoked-control group, would show a reduced bias towards sad faces regardless of the accompanying stimuli (i.e., happy or neutral faces) and an increased bias towards happy faces regardless of the accompanying stimuli (i.e., sad or neutral faces). Further, based on previous research (Armstrong & Olatunji, 2012), this hypothesis was assumed to occurr during later stages of attentional processing (i.e., total fixation duration). However, our results did not support our hypothesis. Indeed, there were no significant differences between both groups in their attentional performance after the training on any attentional index. These results are in line with previous research that, using reaction time paradigms to modify attention, did not find changes in attentional performance after the ABM procedure (Baert, De Raedt, Schacht, & Koster, 2010 – Study 2; Kruij, Putman, & Van der Does, 2013). However, it is important to note that other studies using both reaction times and eye-tracking procedures have found significant changes in attentional performance on different types of samples such as healthy (Ferrari et al., 2016), depressed (Tsumura et al., 2012) and dysphoric participants (Browning et al., 2012).

A plausible explanation for the absence of attentional changes in our results might be due to the differences between our study and previous studies in the control group used. Previous ABM studies have used a modified dot-probe task as a control condition. In these tasks the dot replaced both stimuli presented (e.g., negative and neutral word) the same number of times. Therefore, there is a contingency between the gaze of the control participants and the task performance. Further, in recent eye-tracking ABM paradigms, control participants were trained to attend to negative information (Ferrari et al., 2016) or away from emotional information (Price et al., 2015). These types of control groups might alter attentional processing and produce changes in related variables leading to differences between trained and control participants (Blackwell, Would, & MacLeod, 2017). In our yoked-control group, on the other hand, there was no instruction or contingency between gaze patterns and task performance in the control participants. That is, our control participants were exposed to the same stimuli for the same amount of time that trained participants were but without any constraints. It might be possible that attentional patterns of our control participants during the yoked-task were similar (i.e., maintained their attention on the most positive face) to the attentional patterns of trained participants during the ABM-T. Therefore, these similar attentional patterns might yield to non-significant differences between both groups after the training.

Another possible explanation for our results might be related to the number of sessions and trials used in our training. Previous research has developed attentional training which ranged from hundreds of trials in just one single session (Tsumura et al., 2012) to thousands of trials during several sessions across various weeks (Browning et al., 2012) based on an automatization rationale to modify cognition (Wadlinger & Isaacowitz, 2011). However, Haeffel, Rozek, Hames, & Technow (2012) found that, in a sample of participants with depressogenic self-worth biases, the dot-probe training was effective at modifying self-worth attentional biases but only after the first 20 trials. After this number of trials, the negative attentional bias re-emerged. Further, in a recent metanalysis of ABM in social anxious participants, Price et al., (2017) found a paradoxical dose-response. Those studies that had applied smaller numbers of trials reported significant benefits for ABM in decreasing social anxiety, whereas those that had administered a large number of trials reported no significant differences of the training over control conditions. Therefore, the optimal dose of sessions and trials for ABM procedures remains unclear. Our training consisted of 576 trials administered in two sessions in two consecutive days. Although we applied some methodological improvements, such as feedback or random position of the targets (i.e., horizontal or vertical position), designed to foster adherence and bolster motivation to the task, it could be possible that we did not administer an optimal “training-dose” to our sample. Indeed, our results showed that, although after the first session the positive affect of both groups decreased, after the second session the experimental participants showed an upward trend in their positive affect whereas the yoked-control group did not. Although somehow speculative, it might be possible that an optimal dose, with further sessions, would have lead to significant changes in positive mood in the trained participants.

Further, our ABM task consisted of three training blocks, one for each pair of faces (i.e., happy vs. neutral, sad vs. neutral, and happy vs. sad blocks). in which participants had to localize and maintain their gaze on the most positive face of the pair (e.g., the neutral face in the sad vs. neutral block). However, it is possible that the repetition of the same types of faces within each block diminished participants’ cognitive control and enhanced boredom and fatigue, reducing, then, the efficacy of our training. Indeed, our analyses showed a significant increase in deactivation (i.e., increase in boredom and fatigue; and a decrease in curiosity and entertainment) in both groups after the first session, although this trend diminished in the experimental group after the second session whereas in the yoked-control group it remained stable. Again, it might be plausible that more sessions would reduce the levels of deactivation, decreasing boredom and fatigue, which, in turn, might lead to beneficial effects from ABM-T. Additionally, although somewhat speculative, a random presentation of the different type of trials (i.e., happy vs. neutral; sad vs. neutral; and happy vs. sad) might have led to a greater use of top-down attentional strategies and thereby enhanced the adherence to the task, which, in turn, might have improved the efficacy of ABM-T.

Finally, another plausible explanation for our results is related to the sample's characteristics. First, although our sample size is similar to previous studies (Browning et al., 2012; Tsumura et al., 2012), and although we calculated it through power sample size analysis (Erdfelder, Faul, & Bucjner, 2009) based on the recent Cristea, Kok and Cuijpers metanalysis (Cristea, Kok, & Cuijpers, 2015), a bigger sample size might have powered the statistical analysis and might have revealed subtler changes in attentional patterns. Second, previous research has proposed that cognitive biases are distributed following a gradient (Everaert, Duyck, & Koster, 2014). High depressive symptoms are, indeed, positively associated with the magnitude of the attentional bias (see chapter 4 of the present dissertation). It would be logical to think that modifying a maintenance bias towards negative information or a bias away from positive information, these biases should be presented to the participants exposed to the ABM procedure. In the present study, the mean depressive scores of both groups fell in the mild-depression range. It is likely that some of our participants did not show attentional biases towards or away from negative or positive information before the training which, in turn, might have reduced the ability of our ABM-T to produce significant changes in attentional patterns. Therefore, it seems plausible that we should also include the presence of attentional biases as an additional criterion to select participants for ABM studies, rather than relying only on depressive symptoms or diagnosis.

Our second hypothesis was that changes in attentional biases would be followed by transfer effects to related psychological variables such as depressive symptoms, rumination, and affect. Our analysis did not find any differences between groups in any psychological measures after the treatment. However, participants in the experimental group showed a marginal increase in rumination, compared to their baseline levels, after the training. Also, the yoked-control group showed an increase of thought suppression compared to their baseline measure. These results are difficult to interpret due to the absence of differences or changes in attentional patterns after the training. Indeed, these effects might be due to individual differences in both groups. However, it is important to note that instructing dysphoric participants to modify their attentional patterns (i.e., instructing participants to maintain their gaze on positive stimuli) did not produce any iatrogenic effect on them. Therefore, giving explicit instructions in ABM procedures could be a promising strategy for the field as it do not produce any dysfunctional effect and could improve the implementation of top-down regulation strategies (Amir, Kuckretz, & Strege, 2016; Krebs, Hirsch, & Mathews, 2010; Nisgiguchi, Takano, & Tanno, 2015).

Regarding affect, significant patterns between groups on their positive affect were found across the study. Although before the first training session participants in the experimental group reported higher positive affect than their counterparts in the yoked-control group, both groups showed a decrease of their positive affect after the first training session. However, at the end of the training, yoked-control participants showed lower levels of positive affect than participants in the experimental group, despite the absence of differences between groups at the beginning of the second session. Further, this tendency seemed to be maintained before the stress task. In sum, as shown in Figure 6.4, it seems that the experimental group showed an upward trend of their positive affect whereas the yoked control showed the opposite pattern.

Overall, these results are in line with previous studies that have found changes on related measures regardless of changes in attentional biases. For instance, Baert et al. (2012) found an increase of depressive symptoms after treatment in participants with moderate to severe depressive symptoms although their attentional biases were not modified. However, following the rationale of CBM, a change in attentional biases is necessary to modify related emotional variables such as depressive symptoms or affect (Grafton et al., 2017). Therefore, the present results should be interpreted cautiously.

Finally, following previous research (Joormann & Vanderlind, 2014; MacLeod et al., 2012), our third hypothesis was that changes in attentional biases in the trained group would be accompanied by changes in interpretation biases and less emotional vulnerability to a subsequent stress task. However, no differences between groups were found. It has been proposed that attentional biases precede subsequent information elaboration that leads to different emotional regulation processes (see Joormann & Vanderlind, 2014). Therefore, it seems reasonable to expect that if attentional biases were not modified through our training there would be no later changes in interpretation biases. Nonetheless, both groups showed a significant decrease in their interpretation bias. A plausible explanation might be that the same scrambled statements, in the same order, and the same cognitive load (i.e., the number to be recalled) were presented before and after the ABM-T. The rationale of our interpretation bias task (i.e., the Scrambled Sentence Task – SST) is that the cognitive load (i.e., remember the number) reduces cognitive control which, in turn, leads to the emerging of negative schemas and, therefore, negative interpretations when the sentences are being solved. Thus, it is possible that the knowledge and the habituation to the task led to a benign interpretation of the statements due to increased cognitive control and a lack of activation of negative schemes.

Regarding the emotional reaction to the stressor, Grafton et al., (2017) re-meta-analyzed the data of Cristea et al.'s meta-analysis (Cristea, Kok, & Cuijpers, 2015) finding that in those studies where cognitive biases were successfully modified, this modification was reliably followed by significant changes in emotional vulnerability. Therefore, although our stress task induced the expected emotional reaction (i.e., an increase of negative affect and a decrease of positive one), as we did not succeed to changing attentional biases it seems logical that there were no differences on participants' vulnerability.

To conclude, although we did not successfully change attentional patterns by our training, we hope that the proposed study, which aimed to rectify several limitations of previous ABM designs and apply a new ABM strategy through the use of eye-tracking methodology to train participants' attentional patterns, may shed some light in the ABM field and that researchers can apply some of our improvements (e.g., the use of a carefully designed control group, providing feedback contigent to gaze patterns, etc.) to develop future ABM procedures capable of modifying attentional biases in people with depression.

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CHAPTER 7: GENERAL DISCUSSION AND CONCLUSIONS

The main aim of the present dissertation was to develop and apply a new attentional bias training program to modify attentional biases in dysphoria by using eye-tracking methodology. There is extant evidence regarding the role that attentional biases play on both the onset and maintenance of depression (Gotlib & Joormann, 2010) as well as their role in emotional regulation processes (Joormann & Vanderlind, 2014). Over the last several decades, a large body of research emerged to assess and modify these attentional biases (i.e., attention bias modification, ABM). The growing interest in conducting this type of research was due to its relevance to understanding psychopathology and the possible utility of ABM procedures as a therapeutic tool (Blackwell, Would, & MacLeod, 2017). There are, however, some methodological and conceptual limitations that constrain the generalization and reliability of attentional bias assessment procedures and, also, the efficacy of ABM procedures. With the studies presented in the current dissertation, we hope to contribute to a deeper understanding of these procedures in order to help overcome some of these previous limitations in both the assessment and modification of attentional biases as well as to develop and apply a new eye-tracking program to modify attentional biases using a theory-driven paradigm. In this section these contributions will be presented.

First, in **Chapters 1 and 2** we have provided a general overview of the role that cognitive biases (especially attentional biases) play in depression and dysphoria, also describing the main limitations that, in our opinion, constrain the reliability and generalization of previous attentional biases assessment studies. Second, in **Chapter 3 and 4**, we described three studies aimed at overcoming the previous limitations observed in attentional bias assessment. Specifically, in **Chapter 3,** we developed and validated a set of emotional stimuli controlling for the influence of some psychophysical properties (i.e., contrast energy, luminance, and teeth visibility) that may alter both the emotional judgments (Study 1) and the attentional processing (Study 2) of the stimuli. In **Chapter 4**, using the stimuli selected via the procedures described in Chapter 3, we assessed attentional biases when emotional information (i.e., happy vs. sad faces) are presented simultaneously. In this chapter we also tested whether the influence of depressive symptoms in attentional biases follows a gradient (Everaert, Duyck, & Koster, 2014) based on the severity of symptoms. Third, in **Chapter 5**, we described previous studies on ABM focusing on the limitations that these studies presented. Finally, in **Chapter 6**, we described how we developed and applied a new eye-tracking paradigm to modify attentional biases in participants with depressive symptoms.

In the next sections, we discuss the major findings from the studies mentioned above as well as their implications and possible future directions.

7.1. Overcoming limitations on attentional biases assessment

Previous attentional biases research has shown that, in contrast to healthy people, depressed participants show a double attentional bias characterized by a preferential processing of negative information (i.e., increased attentional maintenance to negative stimuli) and a bias away from positive information (i.e., diminished maintenance of attention to positive stimuli) – (Duque & Vazquez, 2015). However, a deep look into the results of previous studies revealed some limitations (i.e., low reliability of the reaction time paradigms typically used; lack of temporal resolution in the assessment of attention biases; lack of control of psychophysical properties of the stimuli used; and lack of simultaneous presentation of emotional stimuli) which limit the reliability and generalization of the results found. In Chapter 3 and 4 we conducted a series of studies in an attempt to overcome these previous limitations.

7.1.1. Should we control the psychophysical properties of the stimuli?

In Chapter 3, we found that teeth visibility alters participants' judgments regarding the prototypicality and the emotional intensity of happy faces. Specifically, happy faces with covered teeth were unexpectedly rated as more prototypical and more intense than normal happy faces (study 1). Contrary to some previous studies (Horstmann, Lipp & Becker, 2012), it seems that blurring the teeth (in happy faces) leads to an increase of their perceived prototypicality and emotional intensity. It is interesting to note that previous studies presented happy faces with closed smiles which seems to make facial configuration less intense (i.e., less contraction of the zygomatic major and orbiculis oculi muscles) than faces with opened mouth (see Frank, Ekman, & Friesen, 1993). In our study, to enhance the control of the experimental stimuli, we compared the same faces but just modified their teeth visibility. Thus, faces only differed in the salience (i.e., brightness and contrast) of the teeth by blurring them through a Gaussian filter. The reduced salience of the teeth kept the muscle configuration of the face constant, which, according to our hypothesis, might lead to increased attention to other emotional areas, such as the eye area, which contains crucial information for emotional processing (Peterson & Eckstein, 2012).

Previous research has consistently found that the eye region is relevant for social interaction and emotional recognition. For instance, processing information from the eye region is sufficient in normal adults to infer what a person is thinking or feeling (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). Compared with the processing of other emotional expressions such as sadness, the eye area seems to be less attended to when happy faces are being processing (Schurgin, Nelson, Iida, Ohira, Chiao, & Franconeri, 2014). Authors have argued that these attentional patterns might be due to the salience of teeth visibility of happy faces (Calvo & Nummenmaa, 2008, 2011). However, eye-tracking studies have shown specific attentional patterns towards genuine and intense happy faces (i.e., "Duchenne smile happy faces"). More specifically, Williams, Senior, Favid, Loughland, and Gordon (2001) found that, when happy faces depicting Duchenne smiles were processed, participants made more and longer fixations in the eye area (specifically the "crows feet" area) than on the same area of sad and neutral expressions. It is important to note that the facial configuration of Duchenne smiles is characterized by a marked contraction of the orbicularis oculi muscle (Frank, Ekman, & Friesen, 1993). Therefore, a plausible explanation for our results is that by reducing the exogenous attraction of teeth visibility (without modifying the facial configuration of the happy face) other areas that provide emotion-related information, such as the eyes, attract more attention from the observer, which may lead to enhanced judgments of their prototypicality and emotional intensity. Indeed, in Chapter 3, we also found that first fixation was longer in the teeth area than in the eye area in normal happy faces, whereas the opposite pattern was found in covered teeth happy faces (Study 2). Although our results point in that direction (i.e., differences in the preferred areas of processing as a result of hiding visible features of teeth might lead to differences in prototypicality and intensity judgments), we cannot prove this hypothesis as the two studies reported in Chapter 3 were carried out using different experimental paradigms as well as different samples. We are currently involved in the design and analysis of a new experiment that combine both paradigms in order to ascertain if the differential attentional processing of covered and normal teeth leads to different emotional judgments.

On the other hand, it would also be reasonable to hypothesize that the use of covered teeth happy faces might reduce the ecological validity of those faces. However, in our opinion, this reduction of ecological validity is accompanied by an increase of the construct validity of the studies that, at this time of research in the field, seems to be necessary. That is, if we want to assess, for instance, attentional biases to emotional information, we should isolate (and present) only those features of the stimuli that contain emotional information. In fact, previous experimental research typically cropped non-emotional surrounding areas of the face such as the neck, the ears, and the hair, in order to reduce all the non-emotional distractors of the stimuli (Calvo & Avero, 2005; Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013; Duque & Vazquez, 2015). As teeth visibility can be considered a distractor that attracts visual attention, the idea of blurring its salience (without modifying the emotional muscle configuration of the emotional face) seems to be adequate to isolate the emotional features of emotional faces.

An important implication derived from these results relates to prior studies using experimental designs that assessed the processing of emotional expression in healthy or clinical samples. Emotional faces are widely used to assess emotion detection or emotion recognition among different types of samples (for examples see Pollak, Cicchetti, Hornung, & Reed, 2000; Batty & Taylor, 2003; Mather & Cartensen, 2003). Our results reveal the possibility that some previous studies, and their conclusions, might have been influenced by uncontrolled variables such the salience of psychophysical properties of the stimuli. Therefore, our results point out that future experimental design should correctly select the stimuli, taking into account, and controlling, all the possible confounding variables that might influence perception and judgement of emotional faces.

7.1.2. Do the psychophysical properties of the stimuli affect attentional bias assessment?

As we have just stated, previous studies have found that psychophysical properties of, for instance, happy faces (e.g., luminance, contrast energy, or the salience of teeth visibility) exogenously draw participants' attention to them (Calvo & Nummenmaa, 2011; Blanco, Serrano-Pedraza, & Vazquez, 2017). This "attentional attraction" effect might lead to confounding or mixed results when attentional biases are evaluated using emotional faces showing teeth. For instance, previous eye-tracking studies designed to evaluate attentional biases have found that both clinical and healthy participants show an orientation bias towards happy faces (when happy faces were paired with a neutral face) – (Duque & Vazquez, 2015) whereas other studies have not (see Armstrong & Olatunji, 2012). Further, it has been also found that, when compared to depressed participants, healthy samples showed a preferential processing of happy faces rather than neutral faces (Armstrong & Olatunji, 2012), although some studies did not find this differences (Sanchez et al., 2013). Our results (Chapter 3) point out that, perhaps, the mixed results regarding attention to happy faces found in previous studies might be due, in part, to the psychophysical properties of the stimuli (i.e., the salience of teeth) instead of its emotional features. It is possible that the presence of salient features on emotional faces (e.g., visible teeth) may result in a inconsistent pattern of findings regarding the attentional processing of happy faces.

In Chapter 4, we found the typical attentional patterns found in previous eye-tracking studies even when the salience of teeth visibility in happy faces was controlled. That is, in a commonly used eye-tracking paradigm aimed to assess attentional biases, dysphoric participants, compared to healthy ones, showed a tendency to spend less time processing happy faces when these faces were paired with neutral faces. Therefore, the teeth visibility of happy faces is a factor that is not strong enough to modify the bias away from positive information typically found in dysphoria (Leyman, De Raedt, Vaeyens, & Philippaerts, 2011). However, our design does not allow us to ascertain if there are differences in the magnitude of the attentional biases regarding the presentation of normal or covered teeth happy faces. More research should be conducted to compare attentional biases under these different conditions (i.e., normal vs. covered teeth happy faces). Additionally, we used a subclinical sample (i.e., healthy people with high scores on depressive symptoms) in our study. Our results suggest that attentional biases follow a gradient (i.e., higher depressive symptoms lead to higher biases away from positive information). Therefore, it is possible that the presentation of covered teeth happy faces may increase attentional biases in clinical populations. Future studies using a mixed between-within design where clinically depressed, dysphoric and healthy participants are exposed to happy faces, with normal or covered teeth, presented in a random order and paired with neutral faces, might shed some light regarding the actual role that teeth visibility has in attentional biases. For instance, although in our study we found the same pattern as previous studies (i.e., a bias away from positive information), it is possible that covered teeth happy faces magnified the differences between happy and neutral faces as covered teeth happy faces did not attract and maintain participants attention on them (see Chapter 3).

Finally, previous eye-tracking studies have also found that depressed patients have an attentional preference to process angry faces (other emotional expressions that typically depict teeth) over neutral ones (Sanchez et al., 2013). It seems reasonable to think that teeth visibility might also alter the attentional patterns observed when angry faces are being processed (Savage, Lipp, Craig, Becker, & Horstmann, 2013). Therefore, future research should explore the influence of teeth visibility in angry faces on attentional patterns.

7.1.3. Competing emotional stimuli and the gradient hypothesis

Previous research on attentional biases has typically exposed participants to an emotional stimulus (e.g., happy, sad or angry face) that is presented paired with a neutral face (see Duque & Vazquez, 2015; Sanchez et al., 2013). However, this type of design just provides information regarding the preferential attentional processing of emotional stimuli versus neutral stimuli and does not allow researchers to ascertain specific biases when different emotions simultaneously compete for participants' attention. A more naturalistic perspective would be to present emotional information simultaneously as is commonly found in the real world. In Chapter 4, we aimed to assess this issue (i.e., happy vs sad faces competing for participants' attention) as well as to assess differences in attentional biases across the different ranges of depressive symptoms based on the idea that cognitive biases are distributed following a gradient (Everaert, Duyck, & Koster, 2014).

First, our results showed an inverse trend between depressive symptoms and attentional biases to happy faces. Higher levels of depressive symptoms were related to an increased attentional preference away from happy faces. More importantly, these results emerged when happy faces were paired with both neutral and sad faces. We also found significant differences between groups regarding their attentional biases. Specifically, the high dysphoric group spent less time looking at happy faces (in both happy vs neutral; and happy vs sad trials) than mild and non-dysphoric groups. Therefore, our results seem to confirm the idea that attentional biases follow a gradient according to level of depressive symptoms.

Moreover, it is important to note that mild-dysphoric participants spent significantly less time viewing happy faces when they were paired with sad faces than when they were paired with neutral ones. This differential pattern did not emerge in either healthy or high-dysphoric participants. Therefore, it seems that presenting emotional information simultaneously (i.e., happy vs sad faces) maximizes the appearance of attentional biases away from positive information, but only for those participants with mild levels of depressive symptoms. Future studies that aim to assess emotional processing in mild-dysphoric participants should be aware of this effect and use these types of trials instead of the common happy vs. neutral comparison. Additionally, further studies, using clinical samples, are necessary to assess the effects of simultaneous presenting emotional information on the attentional biases of clinically depressed patients.

Second, it is important to note that the attentional bias towards negative information (when it is paired with neutral information), found in depression (Duque & Vazquez, 2015) and dysphoria (Leyman et al., 2011), was not found in our study.

According to our results, a preferential attentional bias away from positive information seems to characterize dysphoria rather than a preferential processing of negative information. That conclusion has also been found in previous studies where dysphoric participants did not show attentional biases towards negative information (Sears, Newman, Ference, & Thomas, 2011; Sears, Thomas, LeHuquet, & Johnson, 2010). Although somehow speculative, it might be hypothesized that in early stages of depression, or at subclinical levels, a "potentially protective" attentional bias (i.e., a bias towards positive information) is diminished, whereas at later stages of the disorder, or at clinical levels, biases towards negative information might then emerge. These results highlight two different ideas. First, attentional biases depend on the course of the disorder and level of symptoms. Second, a biased processing of positive information might be more relevant to the onset of depressive disorder than a bias towards negative information. In fact, recent research has highlighted the central role that positivity (i.e., positive affect and positive cognitions) plays in psychopathology (Vazquez, 2017; Blanco & Joormann, 2017) and, specifically, in depression (Watson & Naragon-Gainey, 2010). It is possible that the absence of a positive protective bias (i.e., the tendency to preferentially processing positive information) is a crucial cognitive mechanism in the onset of depression and that negative biases (i.e., the tendency to preferentially process negative information) only emerge, as a maintenance factor, once the depressive disorder has been established or when an individual faces a stressor. Previous research on vulnerable populations has found that, for instance, after a negative mood induction used to facilitate the emerging of negative schemas, girls at risk of depression (i.e., daughters of mother with major depressive disorder), compared to a non-vulnerable group of girls, showed a preferential attention to sad faces (Joormann, Talbot, & Gotlib, 2007). However, in another similar study where negative mood induction was not used, authors found that children at risk of depression showed, in comparison to non-vulnerable controls, an attentional bias away from sad faces (Gibb, Benas, Grassia, & McGeary, 2009). Therefore, more longitudinal research with high vulnerable participants is needed to address this issue and ascertain the temporal course of attentional biases. Additionally, it would be interesting to analyze which variables (e.g., depressive symptoms, clinical status, affect, well-being, etc.) are involved in the emerging of attentional biases towards both negative and positive information. For instance, recent research in psychopathology has conceptualized psychological disorders as a dynamic network structure where the interrelation (and the strength of interrelation) between symptoms and associated constructs (e.g., cognitive processes) can vary across the development of the disorder (Boorsbom & Cramer, 2013; Bernstein, Heeren, & McNally, 2017). Therefore, this type of approach to psychopathology might shed some light on the dynamic course of attentional biases and the specific symptoms that are related to each type of attentional bias (i.e., a bias away from positive information or a bias towards negative information). Finally, future research assessing attentional biases when other emotional information is presented simultaneously (i.e., sad vs angry; or happy vs angry) is necessary to analyze the specificity of attentional biases to depression-related stimuli when other emotional information is presented at the same time.

In sum, and taking the results of chapter 3 and 4 altogether, we believe that we have shed some light on the limitations found in previous attentional biases assessment research. However, more research is needed in order to keep walking toward the development of more refined methods to assess attentional biases in depression.

7.2. Overcoming limitations of attention bias modification (ABM)

Previous research on ABM has shown inconsistent results on its efficacy to modify both attentional patterns and clinical variables such as affect or depressive symptoms (Cristea, Kok, & Cuijpers, 2015; Mogoaşe, David, & Koster, 2014; Grafton et al., 2017). Some studies have found that ABM tasks are able to modify attentional biases in depression or related clinical variables (Tsumura, Shimada, Nomura, Sugaya, & Suzuki, 2012; Wells & Beevers, 2010), whereas other studies have not (Kruijt, Putman, & Van der Does, 2013; Baert, De Raedt, Schacht, & Koster, 2010 – Study 1). A plausible explanation for these mixed results might be due to some limitations (e.g., the use of reaction time paradigms, the lack of adequate control groups, etc.) in the current procedures used to modify attentional patterns. With the methodological and conceptual improvements described throughout the present dissertation (i.e., controlling psychophysical properties of stimuli, assessing the simultaneous presentation of emotional information, administering trial-by-trial feedback, using a yoked-control group, and assessing training transfer effects), it was expected that some prior limitations could be overcome in developing our eye-tracking ABM procedure (ABM-ET). Furthermore, the application of this new ABM-ET in a sample of dysphoric participants (Chapter 6) would allow us to test if training visual selective attention using eye-tracking methodology could be a promising avenue for future ABM procedures that will need to be soundly grounded in current theories of depression.

The rationale underlying our ABM-ET study was theory-driven as we aimed to modify both attentional biases that have been typically found in depression (i.e., difficulties to disengage attention from negative information and difficulties maintaining attention on positive information) – (Duque & Vazquez, 2015). For pairs of sad-neutral faces, participants had to search for the less negative face of the pair and to keep their gaze for a given amount of time on that stimulus. The attentional difficulties in depression are, in part, related to excessive engagement with negative information, and, therefore, procedures directly aimed at reducing excessive attentional maintenance and difficulties disengaging attention from negative sources of information are conceptually appropriate (see Sanchez et al., 2013; Duque & Vazquez, 2015; Armstrong & Olatunji, 2012). On the other hand, for pairs of neutral-happy faces, the participants' task was to identify the positive emotion and then keep their attention on it. This experimental set-up is also supported by theoretical argument. In an extensive review of the literature on neuroimaging studies, Disner, Beevers, Haigh, & Beck (2011) showed that depression is characterized not only by an attentional bias toward negative stimuli but also by a tendency to filter out positive stimuli. Therefore, in the case of depression, it is conceptually congruent to work simultaneously with interventions addressed at modifying both types of biases. In order to target impairments due to this co-occurring double bias, we simultaneously combined the training of both attentional patterns (i.e., in trials of happy-sad faces, participants should both avoid sustaining their attention on negative information as well as sustain it on positive information). Further, the presentation of different conditions of processing (i.e., detect and maintain attention on the less negative picture in sad-neutral trials; detect and maintain attention on the most positive picture in happy-neutral, happy-negative trials) requires a degree of top-down attentional control implementation that participants may learn to extend in real-life demanding situations, characterized by dynamically changing emotional contexts. The guidance of attentional processing in our procedure was achieved by the introduction of external contingencies to provide performance feedback (Price et al., 2015; Sanchez, Everaert, & Koster, 2016). However, despite the methodological and theory-driven improvements in our procedure, we did not succeed either at changing attentional biases of dysphoric participants or at modifying clinically relevant variables such as affect, depressive symptoms, interpretation biases or stress vulnerability.

In the previous Chapter (Chapter 6), we have already widely explained and discussed the results and limitations of our study (providing some ideas for the development of new ABM-ET procedures). Therefore, in the next section, we will discuss some possible next steps of ABM research and why the development of ABM procedures are still necessary in terms of clinical utility and dissemination of interventions.

7.1.1. What is the next step?

Experimental research has provided some evidence regarding the causal relationship between attentional biases and depressive symptoms and related variables such as affect or stress vulnerability. Previous studies have found that changes in attentional patterns have effects on clinical variables such as depressive symptoms (Browning, Blackwell, & Holmes, 2012; Wells, & Beevers, 2010) or affect (Tsumura et al., 2012). However, the clinical utility of ABM procedures remains unclear due, in part, to the challenge of including adequate control groups that allow researchers to compare the results of active attentional training with pure control conditions. As it has been widely described across this dissertation, control groups currently used in ABM studies are based on sham training (with contingencies between the gaze and the emotional stimuli) or training control participants' attention in the opposite direction than the experimental group. Therefore, these designs do not allow researchers to draw clear conclusions regarding the clinical efficacy of ABM procedures (Blackwell, Would, & MacLeod, 2017). In our study, we designed a yoked-control group in an attempt to overcome this limitation. However, our results did not yield any significant differences between the experimental group and the control group regarding the main outcomes of our experiment (i.e., attentional biases and depressive symptoms) as both groups were inefficacious in achieving attentional and depression-related changes. Despite that our control group seemed to work in the intended direction (i.e., after the control task they did not show any changes on their attentional patterns), participants in our experimental group did not show the expected improvement of their attentional biases. It is possible that, despite the spatial accuracy of eye-tracking paradigms to assess attentional biases, ABM paradigms lead to subtle changes in attentional processing that eye-tracking devices are not able to capture. Other types of attentional tasks such as the attentional blink paradigm, which assesses the temporal components of attention, might be more promising methods of assessing subtle changes after ABM procedures (Sigurjónsdóttir, Sigurðardóttir, Björnsson, & Kristjánsson, 2015).

Additionally, current ABM procedures (based on the automatization of attentional patterns through the repetition of hundreds of trials) have been described by participants as less interesting than other cognitive bias modification procedures like training in changing interpretation biases (Beard, Sawyer, & Hofmann, 2012). Despite that, in an attempt to foster adherence to the task in our study, we introduced some methodological improvements such as trial-by-trial feedback, providing explicit instructions, etc., our results showed that the positive affect of both groups (i.e., experimental and yoked-control groups) was significantly reduced after the first ABM session. In addition, their boredom, fatigue and lack of curiosity and entertainment significantly increased. As can be concluded from our results, it is plausible to hypothesize that a reduction of trained participants' engagement in the cognitive training might impair its efficacy. Future research should try to keep participants' motivation high during the performance of ABM tasks. A promising way to accomplish this aim might be the introduction of some implicit and explicit motivational components found in current serious game research. Certain principles of this new field of research and intervention have been successfully applied to reducing, for instance, attentional biases in adolescents with substance use problems (see Boendermaker, Peeters, Prins, & Wiers, 2017). The application of these principles in other samples such as people with depression should be a main objective for future research.

Finally, an important question arises: Who can benefit from ABM procedures? A growing tendency in clinical psychology research, called "personalized psychology", is being developed to determine which treatment is beneficial for which patient based on their own psychological and demographical variables (see Simon & Perlis, 2010; Cuijpers, Reynolds, Donker, Li, Andersson & Beekman, 2012). The translation of this idea to the field of ABM research might bring some new ideas to clarify which individuals can benefit the most from ABM training as well as might help explain the inconsistent results found in previous studies. Indeed, it seems logical to think that depressed individuals who exhibit a greater tendency to attend to negative information instead of positive information would be benefit more from the attentional training. Therefore, the use of the presence of attentional biases towards emotional information as an inclusion criterion for ABM studies might help to clarify the efficacy of ABM to modify attentional biases. Further, ascertaining which variables are most involved in promoting improvements of attentional biases seems to be a crucial aim of future research.

7.2.2. Should we keep working to develop new ABM procedures?

It is a fact that the range of psychological treatments available to treat psychological disorders has considerably increased in recent years, especially in terms of the development of evidence-based treatments (see Nathan & Gorman, 2007). Guidelines, manualized treatment, and randomized controlled trials are expanding their presence in the research agenda. However, the impact and burden of psychological disorders, in terms of both individual suffering and societal cost, are also growing (Tortella et al., 2016; Kazdin & Blase, 2011). For instance, regarding depression, and notwithstanding the wide range of treatments available, the World Health Organization (WHO) estimates that by 2020 depression will be the second leading cause of disability worldwide (Murray & Lopez, 1996). Further, current interventions for depression (psychological and pharmacological treatments) have shown limited efficacy in both recovery and relapse prevention (Cuijpers, van Straten, Bohlmeijer, Hollon, & Andersson, 2010). In fact, the relapse rate of depression in the year following recovery is estimated around 50% (Kessler, Zhao, Blazer, & Swart, 1997), whereas this rate increases to about 80% within a 15-year time-period (Mueller et al. 1999). These epidemiological data have triggered all the alarms regarding the need of new approaches to reduce the incidence and prevalence of this psychological disorder by developing new prevention and treatment strategies that are accessible to the entire population. To overcome this challenge, it is not enough to simply develop new treatments. Instead, we also need to gain a better understanding of the mechanisms underlying psychological disorders, as well as to know the mechanisms of action of the available interventions (Tortella et al., 2016, Kazdin & Blase, 2011). Research on CBM procedures in general, and ABM ones in particular, might help to address and overcome some of these challenges in depression since their use allows us to identify, understand and modify the causal cognitive factors related to psychopathology (Blackwell, Would, & MacLeod, 2017).

Attentional biases have been conceptualized as a causal factor for the development and maintenance of depression (Vazquez et al., 2010). Therefore, the development of efficacious ABM procedures, capable of modifying specific attentional components of biased attention in depression (i.e., maintenance of attention in negative information; avoidance of positive information) and their clinical related variables such as symptomatology, or mood, would provide theory-driven clinical interventions. On the other hand, the low accessibility of psychological interventions by a large part of the population makes it necessary to develop low-cost interventions that can be accessible to the people who need them most. The increasing use of new technologies has opened a new window for psychological treatment delivery and fostered the research and development of new internet and smartphone-based interventions available to the general population (Kazdin & Blase, 2011). The easy application of ABM procedures facilitate the feasibility of their use as Internet and smartphone-based interventions. Indeed, ABM procedures applied through internet and smartphone devices in other clinical populations such as anxiety disorder have increased in the last decade (Neubauer, von Auer, Murray, Petermann, Helbig-Lang, & Gerlach, 2013; Enock, Hofmann, & McNally, 2014). The development of an efficacious ABM paradigm in depression that could be translated to the internet or smartphone delivery would bring the possibility of having a valuable clinical tool available to boost evidence-based treatments (e.g., using ABM as a treatment adjuvant tool), treat depression, and reduce relapse rates. This ABM paradigm also could serve as a preventive tool for the development of the disorder.

In the present dissertation, we tried, unsuccessfully, to develop a new ABM paradigm based on eye-tracking methodology in an attempt to modify attentional biases in a dysphoric population and overcome the limitations of previous studies. Despite the inconsistent results from our training, we still believe that ABM procedures are a promising clinical tool due to their theory-driven design, their accessibility and their easy application.

Although the current ABM procedures available have yielded inconsistent results regarding their efficacy as clinical tools, there is still significant room for improvement. We hope that the work developed in the present dissertation serves as another step in the development of new ABM eye-tracking procedures to reduce the incidence as well as the prevalence of depressive disorders.

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